TEXTILES

A · HANDBOOK · FOR THE · STUDENT · AND · THE · CONSUMER ·

WOOLMAN AND McGOWAN

TEXTILES

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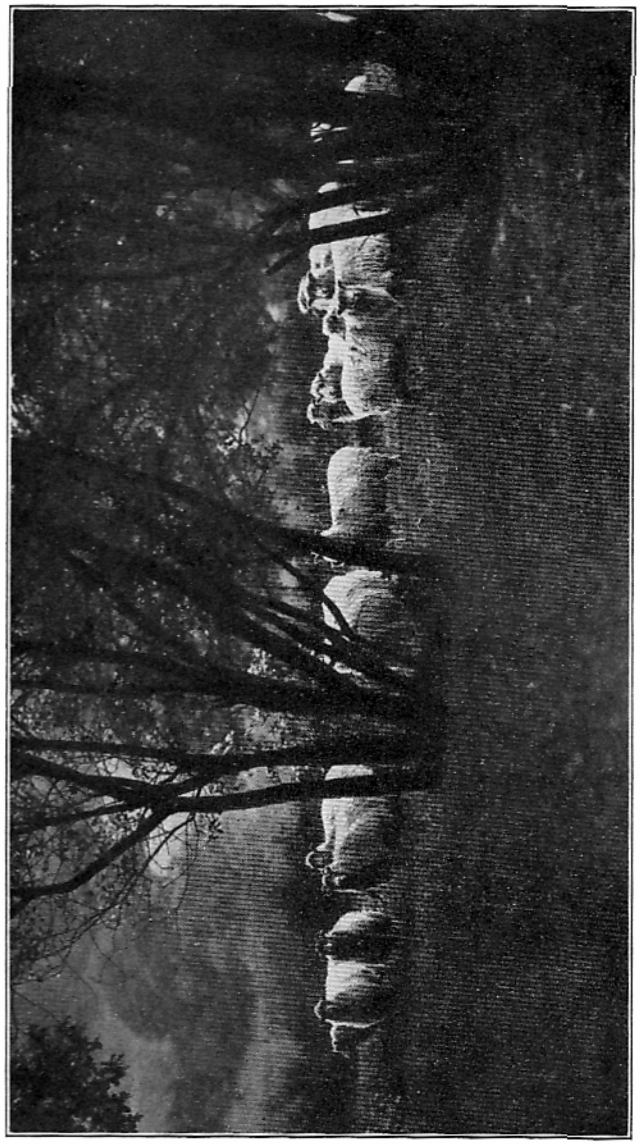

TEXTILES

A HANDBOOK FOR THE STUDENT AND THE CONSUMER

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PREFACE

This book is the result of twenty years' experience in teaching textiles to college students. It is intended as a textbook for college classes or for study clubs and as a guide for the housekeeper or individual consumer of textiles and clothing, the teacher, the club woman, the saleswoman, and as an introductory survey of the subject for the student who contemplates professional work in the textile industries.

The growing emphasis upon textile study in college departments of home economics or household arts, and the increasing use of the textile industry as teaching material in other departments and other grades of schools, shows a recognition of the part that the textiles are playing in the development of civilization and in our everyday life. Interest in the subject is still further accentuated by the movements now on foot to regulate the social-economic conditions in the textile and clothing industries and to secure standardization and honest labeling of textile products, as is being done for food products by the "pure food laws."

To meet the existing need the authors have attempted to prepare a text suitable for use in college classes or by the public, shorter and more readable than the technical handbooks, yet sufficiently thorough and comprehensive to give a sound grasp of the subject as a whole with so much of the technology as is directly helpful to the consumer and as should be included in general courses in colleges and technical or vocational schools.

This has been a difficult task and could scarcely have been brought to a successful conclusion without the coöperation of the experts who have guided the authors, read the manuscript, and suggested ways of dealing with certain intricate and changing processes so as to make the book scientifically and technically accurate while non-technical in form.

With full appreciation of the time this service has taken in the busy lives of the experts, the authors express a debt of gratitude to Mr. William B. Sleeper, Mr. James Chittick, Mr. Theodor Quasebart, Mr. Gordon Donald, Mr. Franklin W. D'Olier, Mr. George F. Smith, and Professor H. T. Vulté of Columbia University, who have read the technical chapters of the book, and to Dr. Susan B. Kingsbury and Dr. Benjamin R. Andrews, who have read the social-economic parts. They also wish to thank the manufacturers who have allowed the use of photographs and cuts of machines and also the authors and publishers who were willing to allow the reproduction of pictures from their printed works.

June 10, 1913.

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TEXTILES: A HANDBOOK FOR THE STUDENT AND THE CONSUMER

CHAPTER I

BEGINNING OF THE TEXTILE INDUSTRY

THE building up of the textile industries has been one of the greatest factors in civilization. The object of this chapter is to present the principles of textile manufacture as they existed in their simplest form, before they were obscured by the elaborate parts and adjustments of modern machinery. Modern woman owes a debt to primitive woman, for until machinery was invented she held, in truth, the textile industries in her hand. She was the original inventor and workman. In the earliest times she bent her whole mind to improving the conditions immediately around her. Her work had to do with shelter, clothing, food, and the growing of simple things. She had to gather as well as to manufacture. If she could not find what she wanted, she tried something else, using everything around her which her strong fingers, her sharp teeth, or her rude tools could render available.

Primitive Conditions. — To consider the development of industry in primitive communities is the best way to understand the reasons for some of the present industrial, social, and economic conditions. The need of food, clothing, and shelter caused the early inhabitants of the earth to use the materials spread about them by nature to supply their wants. They were at a great disadvantage in their struggle, for they had not the strength of the animals, nor had they weapons for defense or for obtaining food. They had to fight with nature for life itself, but the results show that they were able to think and act, for they made progress toward control of their environment, and their labors and inventions made the modern world. The sharp stones at their feet were fastened to handles of wood or bone by the aid of rushes or strips of skin, and used for weapons. Branches of trees were interlaced to form carriers, to cover the wet or rough floors of rocky caves, to make a shelter above the entrance, or a defense outside of it. The skins of slain animals were used for many purposes, being laid on top of interwoven branches to form a shelter, thrown on the floor, worn upon the body, or dried, cut into strips by sharp stones, and used for binders and for decorations. Thorns, bones, and twigs served for pins or fasteners of the rude skin cloaks. Sinews, rushes, barks, grasses, reeds, quills, rawhide, and vines were useful for twines, ropes, and handles. Birds' nests, spiders' webs, and other animal industries offered suggestions for using nature's materials at hand. The gourds, the covering of some varieties of palm buds, the cocoanut, and the barks of cedar and other trees were ready for immediate use. Adaptations and changes were made, which opened the way to greater inventions.

Mats for various purposes were made at an early period by tying, twining, twisting, knotting, and interlacing grasses, rushes, twigs, sinews, strips of skin, and fibers of plants when soft material was needed, or split canes, vines, willow, and other branches when rigid forms were desired. Two kinds of materials were often combined in such articles as carriers or baskets. Nets for fishing or for carrying burdens, and traps for catching fish or game, were made in a similar way. Crude attempts at decoration show the birth of design and the instinct for beauty. Mats were woven showing variations of color in design from the turning over of rushes. Fringes of rushes, grasses, and shells were common, and later were used for clothing. A network of knotted grasses added to the attraction as well as to the comfort of the garment. Such grass garments are still worn in the East.

The skins of animals were worn with the fur inside to make them comfortable. The felting of the wool of sheep as it touched the body led the way to the making of felt for clothing. The dried skin was later tanned to lessen its roughness. In some warm countries the soft, juicy inner bark of special trees was pounded into a flexible mass, soaked in water to ferment, and beaten again with mallets and rollers carved to give special effects. Patterns were made on these bark clothes in various ways, leaves and flowers wet with dye being sometimes laid on and pressed down. Bark material is still made. It is supposed to have been a forerunner of felted cloth. The cloth was beaten into large sheets, one being welded to the other, and was varnished with oil to render it waterproof.

Basketry was at first very simple, being made with splints, but it soon developed patterns in diagonals and diapers. The alternation of rigid with pliable materials gave a wide scope for design, and the twined and sewed basketry of some primitive people was an art (Fig. 1). Basketry and weaving have much in common, and improvements in one helped the other. Pottery soon developed, probably from the habit of lining baskets with clay in order to hold water. Some of the most primitive pottery shows the form of the weaving of the basket on the clay. (See Fig. 30.)

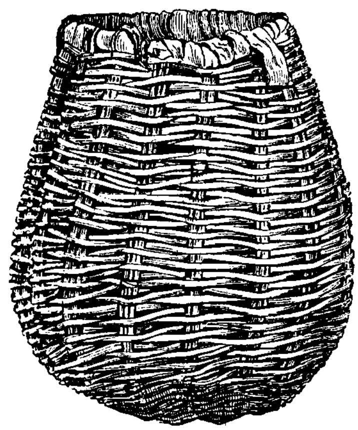

FIG. 1. — WICKERWORK BASKET.

The men were occupied in food getting, in fishing, hunting, and in war, while the women were working at the camp. The discovery of the use of fire tended toward further division of man's and woman's work, for she was the caretaker of the children, and naturally stayed by the fire. As the early people were wanderers, they needed carriers for transporting their young children and their household goods, and mats and baskets served many useful purposes in the life on the march, as well as in the tree, cave, or shelter homes. Inventions were adapted to numerous purposes; for example, a method of holding rigid material by softer fibers twined about it, now called wattling (Fig. 2), was used for shelters by fastening several heavy sticks together in a point, with their loose ends stuck into the earth, laying grass and rushes on top, and holding down this covering by laying sticks at intervals across the grass and rushes, and tying them down by intertwining pliable material around the sticks; for defenses, by holding together the great stakes used for stockades around primitive huts; for early weaving of soft materials, or for very coarse basketry, as well as the fine basket weaving of the Pacific Coast of the United States. Wattling is really a form of weaving. Such a principle once grasped by these awakening minds became a means of development as the environment offered new materials for use, and the many needs gave an impetus.

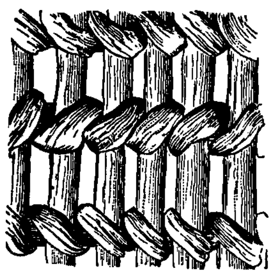

FIG. 2. — WATTLING.

The earliest beginning of the race has well been called the "Age of Fear," for man was afraid of his fellow, afraid of the animals, and afraid of nature. The individual was at first sufficient unto himself; there was little interdependence among the members of families. As family life increased, there arose a tendency to form into small groups. By degrees they entered into alliances with other nomads, thereby increasing their safety and bringing knowledge of new methods of fishing, hunting, and living. These social interrelations tended to decrease fear and to develop industries, for some families had made more progress in the crafts than others, and added comfort and beauty were found to come through new devices. Gradually those who excelled in textile work began to attain prominence, as did the great warrior or the great hunter.

Era of Hunting and Fishing. — During this time many crafts originated and devices to assist labor were invented. Work in metal had begun and was used to improve the textile tools. Although women did some planting, the homes were moved too

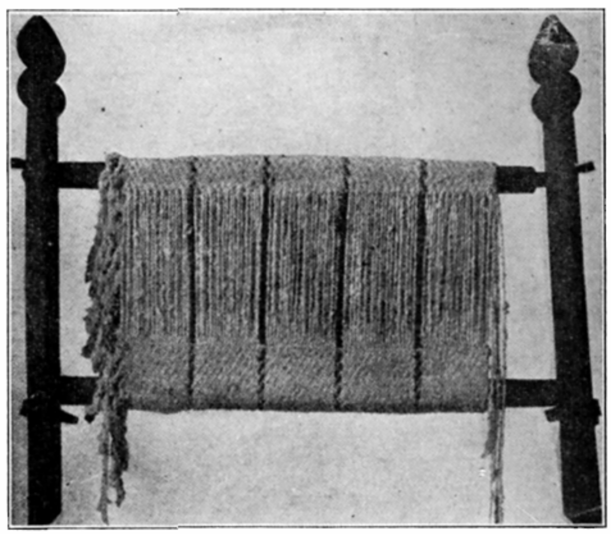

FIG. 3.—A PRIMITIVE TYPE OF LOOM.

frequently for the maintenance of a settled agriculture. There was little trade between people, and little providence for the future in storing food or in making covering, for all extras impeded travel.

During this wandering life the important industries passed their simplest form. Weaving was now done on looms, which were nothing more than two heavy sticks between which rushes were stretched so that the latter were held taut, while the weaver wove other rushes across these threads (Fig. 3). The value of fibers taken from the plants and the coats of animals had been discovered, and crude forms of spindles and distaffs aided in the spinning of yarn. At first, hair, hemp, leaf fibers, strips of fur and sinews were in use, but when it was found that short fibers, such as wool and cotton, could be prepared and twisted continuously around each other, a great step was taken toward weaving (Fig. 4). The first woven articles were more for floor or house covering than for clothing. The advantage of the softer materials for carriers and coverings was soon felt, consequently softer fibers were in demand. Coarse handlike wood contrivances (See Fig. 18) aided in the opening (carding) of the wool or other fibers, so that they could be twisted more easily into yarn. Weaving which combined pattern with color gave results of interest and even beauty, increased by knowledge of dyeing, staining, and painting by the use of crushed berries and roots. Climate, of necessity, had its effect. Tropical regions gave fine, soft fibers which made exquisite weaving possible, while cold countries offered skins and coats of animals to be used for similar purposes. The ease of life in the tropics tended to idleness, but colder climates made it necessary to struggle continually to obtain the necessaries of life. It is in temperate parts that we must look for the greatest industrial inventions and improvement in living.

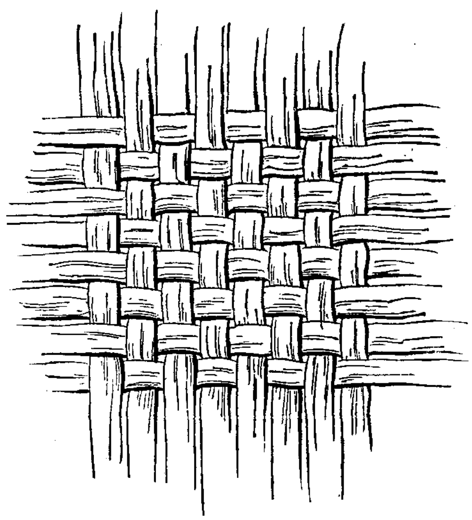

FIG. 4.—PLAIN WEAVING.

Some form of sewing was used in various developing industries, as in basketry. The thorns and bones used for fastening were now made into needles, with an eye to hold the twisted yarn. The bone needle, stiletto, and awl were treasured utensils (Fig. 5).

The increasing knowledge of animals and of means of trapping them led to domestication of the less savage species.

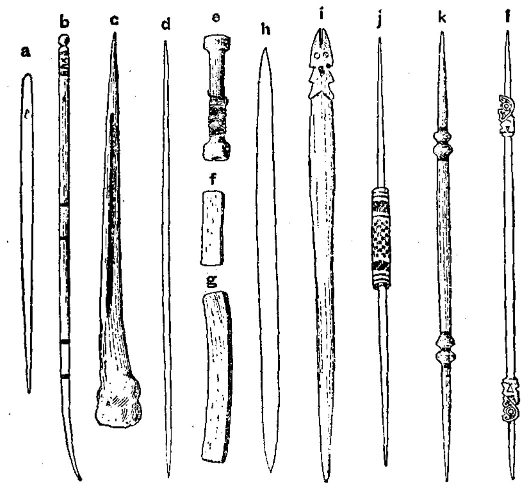

FIG. 5.—PRIMITIVE IMPLEMENTS.

a, b, needles; *c,* bone awl; *d,* needle pointed at both ends; *e,* wooden spool; *f,* netting mesh; *g,* weaving band; *h,* shuttle-like piece cf wood; *i,* netting or weaving instrument; *j, k, l,* spindles.

The effect of the keeping of such domestic animals on problems of food, shelter, and clothing was very great. More permanent homes were established for the women, children, and the less able, while the strong men went out with the flocks and herds, returning at intervals. A pastoral life took the place of the wild and uncertain life of the chase. Care of animals developed a different and less savage temper. Warlike instincts were less constant. Peace between neighboring families increased, and ceremonies showing the pact between them were held around mounds of stone, which became the center of life and government.

The Navajo Indians are present examples of this pastoral life. They settle on land good for grazing, their property being chiefly flocks of sheep and goats, and herds of horses. The flocks give them food, and wool for their rugs, blankets, and lariats. They do some planting, but are not agriculturists.

During the Pastoral Age the industries developed rapidly in spite of the semi-nomadic life. The more stationary home life gave an incentive to the making of rugs, hangings, and clothing, which were often rich and beautiful. The uniting of many families under one leader stimulated the desire to excel, and specialization in some particular textile craft was not uncommon. The wish for social approval led to the adornment of the person, and clothing became more decorative in character. It had been adopted originally to show prowess or to frighten enemies, by displaying the skins of animals slain by the wearer, or by strings of teeth or scalps worn around the body. This custom led to the use of cloth for ornament. A feeling of shame for not wearing clothes came only after dress had become customary. Hats, which at first were inverted baskets, were now made especially for the head covering. The demand for material made from spun wool or cotton increased with the demand for clothing. Dress now became a means not only of comfort or of decoration, but to show the distinction of sex or of classes. Among the Navajo Indians the chief's blanket has its special design and colors, and the dress of the young unmarried women is different from that of the married ones. Special costume was used for the medicine men and warriors, and for ceremonials. The use of dress for social distinction has always characterized developing people. The Middle Ages perhaps saw its height, but although moderated, it is still a part of modern civilization, though now more practiced by women than by men. The demand for fabrics of rare design gave great impetus to the art of weaving (Fig. 6). Tribes began to look to each other for exchange of products, and so tended to assume more peaceful relations.

By the close of the pastoral and the beginning of the agricultural era, many textile industries had passed their primitive

FIG. 6. — PUEBLO WOMAN WEAVING.
From Watson's *Textiles and Clothing*, by courtesy of the American School of Home Economics.

stages. Devices and even rude machinery to assist the hand were common. Beauty of design and skillful handling are evident from examples preserved in the museums. The most common of the textile crafts in use were: —

Braiding and looping.
Tying, wattling, and thatching.
Netting for fish nets, carriers, and clothing.
Weaving for shelters, mats, rugs, hangings, and garments.
Basketry, both woven and sewed, made into carriers, hats, traps, and household articles.
Knitting and crocheting.
Carding and spinning.
Reeling.
Needlework in sewing, embroidery, appliqué, repairing, box making, and clothing.
Lace making, by sewing, weaving, and knitting.
Skin drying and curing.
Dyeing and staining.
Decoration in bead work, stenciling, block printing, and picture writing.
Felting and beating.
Making tools for use in the various crafts.
Loom building.

Agricultural Life. — The time when agriculture became the chief occupation marked an important stage in industrial life. The childhood of the race had passed, but was recalled in its emotional and recreational life. The people now lived in permanent homes and life had become duller on account of its round of constantly repeated occupations. Festivals, dramatic representations, folk tales, dances, songs, and religious ceremonies were instituted. Events in the former primitive life and the all-important industrial processes, such as spinning and weaving, became motives for these performances. Incantations and charms were used to assist young girls in learning to weave. Interest was taken in cultivating textile plants, such as flax and cotton. Sheep were raised in order to provide wool for spinning. Private ownership and a sedentary life increased the demand for household goods. Two classes of textile industries began to be developed, the extractive and the productive. The people gathered together in groups, moved by the impulse toward sociability and the need for mutual help. New social and political relations arose between them, which required the establishment of forms of government. Slaves taken in the frequent wars were made to perform domestic services, hence a new class of industrial worker was available, who did not belong in the home and was considered inferior. A feeling of caste was more apparent, and dress was used to indicate varying conditions of life. The people built their own homes and provided for their wants with occasional help from neighbors. The exchange of a few commodities was the only business relation. Industrial towns developed as trade centers, and additional workers had to be employed in the home workrooms to increase the output. The women were factors in this industrial change, for spinning, weaving, and bleaching were still home occupations.

The Household System. — Entire families soon began to devote themselves to special industries in order to sell to others or to exchange, and many households became economic centers.

This era was in progress in Bible times. In Proverbs 31, the mother of King Lemuel speaks of the work of women in the households as comprising both home use and sale:—

> "She seeketh wool and flax and worketh willingly with her hands."
> "She perceiveth that her merchandise is good."
> "She layeth her hands to the spindle and her hands hold the distaff."
> "She is not afraid of the snow for her household, for all her household are clothed in double garments."
> "She maketh fine linen and selleth it and delivereth fine girdles unto the merchant."

The employer and helpers worked together in the home factories, each owning his own tools. Apprentices learned the whole process and were therefore fair judges of the output as well as workers on it. Great fairs occurred at intervals at which the industrial products of the household were sold outright or exchanged for farm products. Trade difficulties soon made a middleman necessary to collect the goods, sell, and exchange. The demand for bedding, for blankets, heavy serge curtains, flannels, household linens, and homespun materials increased the number of textile workrooms where both men and women worked together. Wherever industries were numerous, great towns began to develop. It was customary for workers to gather around the home of some influential man, giving their services in return for his protection, but the downfall of the feudal system at the end of the fifteenth century cast them adrift and they increased the number of those working in the commerce or industry of the towns. Markets were opened for selling goods, and guilds for both the merchant and the craft worker were organized to help standardize the work, to better conditions, and to give good goods at honest prices. The textile guilds became very influential and did much to organize trade and to train the workers. However, the passing away of the guild system in the seventeenth century deprived the workers of a central body which was responsible for the coördination of capital and labor, and which understood the relation of laborers to each other. There was not at the time any clearly defined division between the capitalists and the working classes, and much of the textile work was still done in the home workroom.

America was colonized about the time of the decline of the guilds, and its industrial life was characteristic of this era of home workshops. The life of the colonists was on the farm. Each home was a self-sufficient unit, and consequently a center of varied occupations. The mother directed the work of her daughters and also paid for such additional help as she could obtain from the neighborhood. The farm occupations were numerous and were in the stage in which homemade machinery and devices were used by the worker. The textile activities

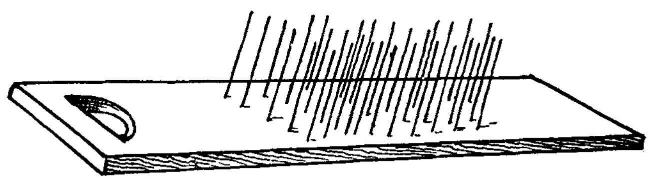

FIG. 7.—FLAX HETCHEL.

in each colonial household were principally carried on by the women. They consisted of carding of wool; breaking, hetcheling, and swingling of flax; wool and flax spinning; winding, reeling, and warping; the weaving of cloth, blankets, and rag carpets; the bleaching of cloth and yarns; sewing; quilting; dress and garment making; embroidery and lace making. The devices and machines used for this work were the cards, hetchels (Fig. 7), flax breaks, the great or wool wheel, the flax wheel, winders, reels (clock and hand), niddy noddy, quill winder, swifts (Fig. 8), warping bars or warping drum, skarne, bobbin frame or creel (Fig. 9), bobbins of many kinds, healds and shafts, the raddle, and the loom. The fathers and sons assisted in the textile work by growing and preparing the fibers and making the machinery and tools. Some small factories run by water power were established in the late eighteenth century.

The Industrial Revolution. — The inventions of Hargreaves, Arkwright, Crompton, and Cartwright brought the modern factory system and with it a new industrial era. Power was now needed to move the spinning frames and looms. Horse and water power were soon succeeded by steam. The markets were extended, for this same steam power made transportation

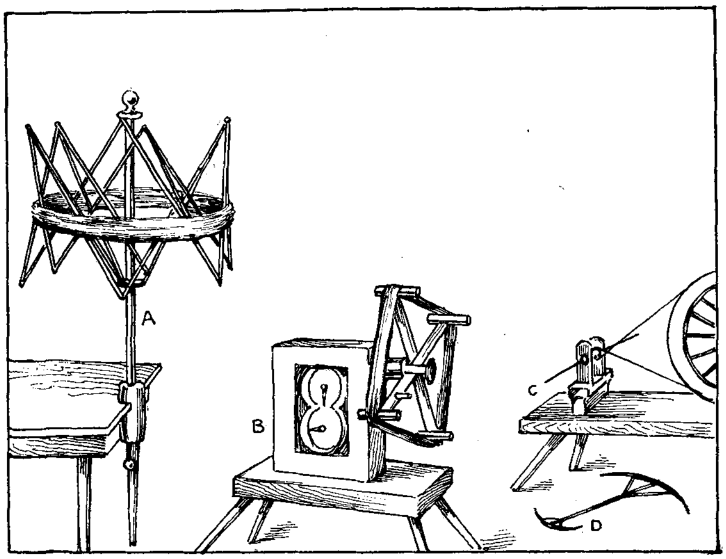

FIG. 8.—*A*, Swift; *B*, Clock Reel; *C*, Quill or Plug Winder; *D*, Niddy Noddy.

easier. An impetus toward increasing the output came as a result of the possibility of selling outside of the environment. Workers of both sexes turned toward the textile factories, for the expense of power had driven the work out of the home workshops into especially constructed and equipped buildings. The isolated workers could not compete with the machines. Capital for the industries was provided by men of means who, unlike the heads of the domestic workrooms, were not of necessity textile workers themselves. They controlled the situation, but often knew little of the condition of workers. Questions of the division of profit between capital and labor began to cause irritation. Competition arose between factories and the sub-

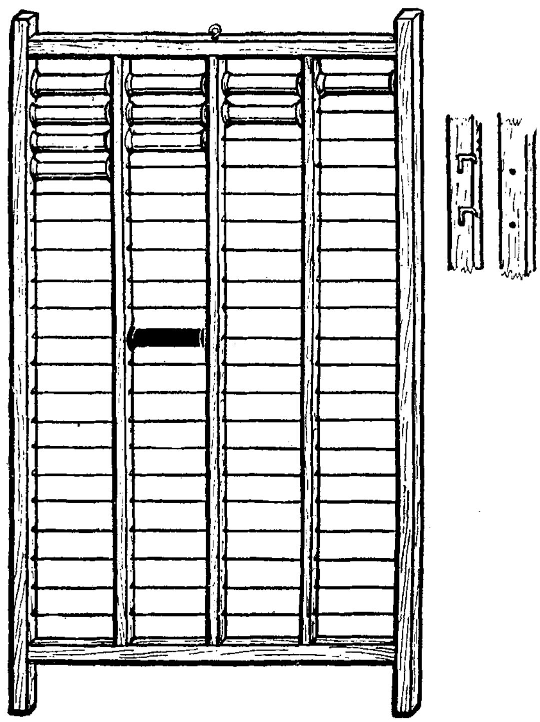

FIG. 9.—BOBBIN FRAME.

From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

division of industry followed as a means of increasing the output through rapidity of work. The worker, therefore, soon lost his individuality and likewise his interest in the perfection of the product. The capitalist increased in wealth, but low wages and poor living were prevalent among the lower class of workers.

A powerful mercantile class began to have voice in national affairs. The economic situation became acute, but gradually from it there developed a new social conscience in all classes, and laws were enacted which aimed to improve working conditions, to limit working hours, to regulate the work of women and children, to prevent industrial accidents or to compensate for them, to improve housing conditions and the sanitation of workrooms. Leagues and societies of workers and employers were organized and are still at work adjusting these conditions.

The industrial revolution is responsible for bringing about great changes for women; for as their home workrooms were taken away and the manufacture of textiles was conducted elsewhere, the women were no longer important economic producers. With this change their knowledge and ability to judge of the content and value of materials passed also. Those who had to labor became part of the huge subdivided activities in the factories and knew only the small part on which they worked. Those who remained at home were entirely removed from participation in the work of making cloth or even knowledge of the methods. The desire for cheap yet pretentious fabrics and the cost and difficulties in manufacturing reliable ones have brought into the market a large supply of untrustworthy and often adulterated materials to satisfy the demand.

CHAPTER II

SPINNING

Carding and Spinning by Hand. — Spinning is the twisting of a succession of fibers into a continuous cord, rope, or yarn. It was one of the earliest industries of the human race, and the necessary opening of the fibers, which were often matted and rough, to make them twist more smoothly, was the beginning of carding. It is supposed that both processes began about the same time. The need of some form of binding twine, and later of mats and shelters, led to the use of rushes, strips of skin, the hair and sinews of animals, the bark of trees, the fibers of the agave and of other plants. These fibers were limited in length, and had to be knotted or twisted together to serve the purpose required. They were not spun. It was later discovered that some fibers lent themselves to continuous twisting. Wool spinning may have been the earliest, for wool was accessible and easily twisted on account of its natural oil and crimp. Flax (linen), though difficult to prepare, was in use even before the age of metals, for the yarn has been found in hanks and also in cloth in the ruins of early dwellings now covered with the mud of some of the Swiss lakes. Pictures on Egyptian tombs show the processes of flax preparation as conducted there at an early age. Cotton was used in India, and the laws of Manu, 1000 B.C., give regulations concerning its manufacture, seriously objecting to the heavy sizing of the yarn, showing that spinning was an old industry at that time. In South America at a very early period cotton was spun into fine yarns and woven into cloths of great beauty. Silk, too, was taken from the cocoons, slightly twisted, and woven into cloth in China and Japan at the dawn of their history.

Early spinning was done by the fingers alone, the fibers being held in the left hand and twisted with the right (Fig. 10). It

FIG. 10. — SPINNING WITH DISTAFF AND SPINDLE.

From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

is a very simple process. Even a little twist greatly strengthens the fibers. The spinner drew from prepared (carded) fibers, such as cotton or wool, a number of parallel threads and twisted them as they came, making a continuous piece. It took a little practice to make a firm, even yarn. As the fibers thus spun untwist very quickly unless held by some artificial means, the discoverer probably wound the product on a stick, later fastening the end of the yarn in a natural or manufactured cleft, or holding it by a half hitch around the stick. It was seen that if the stick or spindle on which the spun fiber was wound and caught slipped from the hand while the spinner was twisting in another length, it would revolve rapidly in the other direction and untwist the length of yarn. Experiment would show that by giving the spindle a sharp twirl as it descended, carrying the length of yarn, a twist might be put in during the time the revolutions continued. A spindle on which a quantity of spun yarn was wound would be found to revolve more smoothly and draw out the fibers better than one which had no yarn on it; this suggested the placing of a weight on the spindle. A lump of mud or clay, a stone or a piece of wood were early added to the spindle to assist the revolutions. It also kept the yarn from slipping off the spindle. Such weights, called whorls (See Fig. 5, *j.*), were often molded, carved, or painted attractively.

Good spinning required careful carding of the fibers. Some means other than the hand of holding these opened-up fibers was necessary in order to keep them in good condition. At first a simple stick was used, at one end of which the carded mass was placed, lightly tied around with a piece of yarn to keep it smooth. This stick was called the distaff. It was held under the left arm or in the belt, or it was thrust into the ground beside the spinner. In Germany it was called the rock (Fig. 11), and was placed on a block to hold it erect, while the spinner stood or sat near by. In parts of the Continent spinning with the distaff and spindle can still be seen. The spinner draws out a number of fibers from the under side of the carded material next to the distaff, twists them, and fastens them to the end of the spindle. With the right hand she gives a sharp twist to the spindle; in the meanwhile, she continues to draw out a number of fibers with her left hand to supply the descending spindle. When the spindle reaches the ground, she picks it up, winds on it the length of thread just spun, and catches the end in the cleft (Fig. 12). Spindles were made of wood, bone, and metal. They were usually from ten to twelve inches in length, while the distaff was from twelve to thirty-six inches in length.

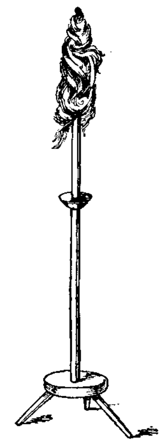

Fig. 11. — Rock.

Spinning is found among all primitive people, and although it differs in method, the underlying principles are the same, *i.e.*, drawing out the fibers, twisting them, and winding them up. Rope making was similar to spinning. The worker held the raw material, such as hemp or flax, in the hand or apron, and after attaching some of the fibers to a revolving device, walked backward, letting out the material. It was thus drawn and twisted. The required length of rope was made by extending the twisting for a hundred or more feet and then returning, to allow it to be wound. The single ropes thus made were united in threes, making a heavier rope. Ropewalks across fields are still found in Europe. In India we find a method of spinning the finest grades of cotton yarn by revolving a thin piece of bamboo in a cup of cocoanut shell. The fineness of the yarn to be used for Dacca muslin has never been surpassed by machinery. A simple method of spinning coarse yarn for hammocks

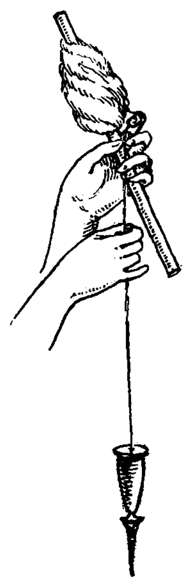

Fig. 12. — Hand in Action.

Fig. 13.—Navajo Woman Spinning.

or twine was found in New Guinea. The worker laid a bundle of fibers on the left knee, pulled some threads from it with the right hand, twisted them, and rolled them into a ball on the right knee. Another method of spinning was to tie fibers to a stone and revolve the stone. The Navajo Indian women of New Mexico and Arizona have for a spindle a slender stick of wood with a circular disk or whorl at the end of it. The woman sits on the ground with her slivers of carded wool beside her, holds the spindle with her right hand, and puts the point of the spindle on the ground with the whorl just above it. She lays the long end of the spindle against her knee, attaches the end of a sliver close to the disk, holds it out and draws it away so that it grows thinner and is twisted as she twirls the spindle. When a length of yarn is sufficiently attenuated and spun, she winds it on the spindle. This process is repeated until the spindle is full (Fig. 13). The first yarn spun is soft and only slightly twisted, consequently the process is repeated several times until it is strong enough, especially for the warp threads.

Spinning by Wheels. — Between the fourteenth and sixteenth centuries spinning wheels began to take the place of the distaff and spindle. The latter method had supplied the yarn from the dawn of history until the Middle Ages. Fabrics in museums testify to the skill, patience, and instinct for beauty in the women of the past. The process was, however, so slow that a more rapid method was necessary to increase the supply of yarn. India at a very early period invented a method of spinning by attaching a wheel to the spindle by means of a band, causing the latter to rotate. It was called the Gharka or teakwood wheel (Fig. 14).

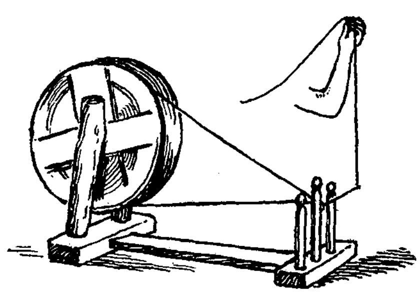

Fig. 14. — The Gharka Wheel.

The spinner sat on the ground beside the wheel and supplied the spindle with raw material. The India wheel was a very rude instrument, but could spin a coarse yarn; the fine spinning of India continued to be done by the revolving spindle propelled by the hand.

The Great Wheel. — In Europe early in the fourteenth century a single-thread wheel was used which was similar to the India wheel. The idea may have been brought from India, or it may have been original. In England this wheel was called the Jersey, the Great, or the Wool wheel, and in Scotland the Muckle wheel (Fig. 15). It was principally used for wool, as its slow, intermittent motion was well fitted for short staple fibers which easily pull apart after being carded into the roll or sliver form. The one-thread wool wheel differed slightly in various places. It was found in both the high and low form. At first the great wheel directly revolved the spindle, the latter being in a horizontal position, but later a large wheel drove a smaller one, which again turned the spindle by means of a wharve or small grooved pulley fastened on the end of the spindle. The wharve was a development of the whorl.

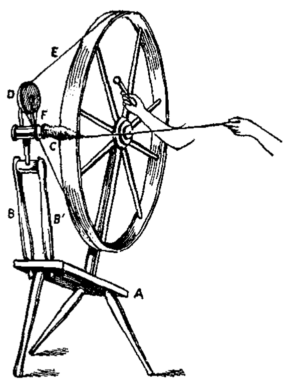

Fig. 15.—The Great Wheel.

The Parts of the Great Wheel were: I. The standard (*A*) on three legs, on which were the two upright posts (*B*, *B*) which held the spindle (*C*) in a horizontal position. A wharve or pulley was at one end of the spindle, and a small wheel (*D*) provided with a pulley or groove. At the other end of the standard (*A*) was a post which held a large wheel. II. A band or cord (*E*), which connected the large wheel with the small grooved wheel (*D*). III. A cord (*F*) which connected the small grooved wheel with the wharve or pulley on the spindle.

The Motion of the Great Wheel. — By revolving the great wheel by hand the small wheel turned very rapidly, communicating motion to the spindle through the wharve or pulley, consequently the spindle turned as long as the great wheel revolved.

The Method of Spinning on the Great Wheel. — The wool or cotton was first carded by hand combs into soft rolls a foot or more in length and a little less than two inches in width. (See Fig. 18.) The spinner stood beside the wheel. An end of spun yarn had been left on the spindle to which she attached a roll, or, if not, she drew and twisted by hand a short length of yarn from one of the rolls and fastened that to the spindle. She brought the end of the twisted yarn to the point of the spindle, and held the remainder of the roll in her left hand. In her right hand she usually held a wooden peg, with which she struck a spoke of the great wheel, causing it to revolve and the spindle to turn. She gently drew the roll away from the spindle almost on a line with it. As the roll became attenuated, the revolving spindle twisted it into yarn in the same way that the revolving vertical spindle had twisted the yarn when it was spun by the hand of the worker. When the roll was drawn and twisted almost to its end, she stopped the wheel. By turning the wheel slowly in the opposite direction the spun yarn, which extended to the end of the spindle, backed off to the center of the spindle or to any point that the spinner desired. The yarn was now at right angles with the spindle. The spinner again turned the wheel in the original direction, thereby winding the length of spun yarn up on the spindle. She was now ready to piece on another roll. She laid one end of it over the end of the one just spun, again drew the end of the twisted part of the yarn to the end of the spindle, and repeated the process as described. She thus repeated the three principles required in the earliest spinning, *i.e.*, (1) Drawing or attenuating the fiber, (2) Twisting it, and (3) Winding it up on the spindle. She did this in two parts or intermittently; the first division drew and twisted the yarn, the second wound it up. As has been said, the motion of the great wheel was intermittent. For soft yarn, made of easily separated fibers, this was a decided advantage, for it did not put too great a strain on the yarn by winding it while it was being drawn or twisted. The wheel was the progenitor of the modern mule, the motion of which is also intermittent. The yarn was respun several times before it was strong enough to be used for warp threads. When the spindle was full of yarn the thread was wound off on a reel. (See Fig. 8.) In general, the yarn from the great wheel was more satisfactory for the filling than for the warp threads. At the low wheel the spinner sat, but at the high one she stood, walking back and forth at her work. It is said that twenty miles a day were frequently covered by spinners on the wool wheel in our colonial times. The great wheel spun several times as much yarn in a given time as the distaff and spindle, and relieved the pressure for more yarn, but the cry for better warp thread still continued, and was met by the Saxony wheel.

The Flax, Saxony, or Leipsic Wheel was invented, it is said, by Jurgens in Germany about 1530. It is probable, however, that wheels of a like character had been made before that time. This wheel was an elaborate piece of mechanism as compared with the wool wheel. The foot was used as power, consequently the hands were free to draw out and guide the fiber to the spindle. The Saxony wheel was well adapted to the spinning of flax, for the principles of drawing, twisting, and winding were continuous, which made a strain on the yarn which flax could stand better than wool or cotton. The latter fibers were, however, spun upon it, not from the distaff, but from rolls of carded material fed by hand directly to the spindle, thus lessening the strain. There are several models of this wheel. A common one, though not the earliest form of it, is seen in Fig. 16.

The Parts of the Saxony Wheel were: I. The frame (12) which stood on three legs, the wheel end being lower than the distaff end. II. The wheel (1) had an iron bar through its hub by which it was supported in the deep grooves of two upright bars of wood (11*a*, 11*b*). III. The distaff (10) was supported on a high standard at the opposite end of the frame from the wheel. IV. At the distaff end of the framework two upright bars (3*a*, 3*b*) supported the spindle (6), which was made of polished steel, and had a pointed end protruding through a leather ring on the upright bar (3*b*) away from the spinner, and a needle end (4) (in which was an eye) through another ring in the bar (3*a*) toward the spinner. A flyer (2) was fastened about one inch from the needle's eye, and a large wharve or pulley one inch from the pointed end. A cord from the wheel caused the revolution of the spindle. The flyer had a series of hooks or guides over which the yarn was passed before it was delivered to the bobbin (7). The turning of the flyer twisted the fibers, which were threaded through the needle's eye, and wound them up on the bobbin. The spinner changed the yarn from one hook to the other of the flyer as she spun, and gradually filled the bobbin evenly with yarn from end to end. The flyer went round very rapidly, but the bobbin was kept back by the friction of the yarn which was

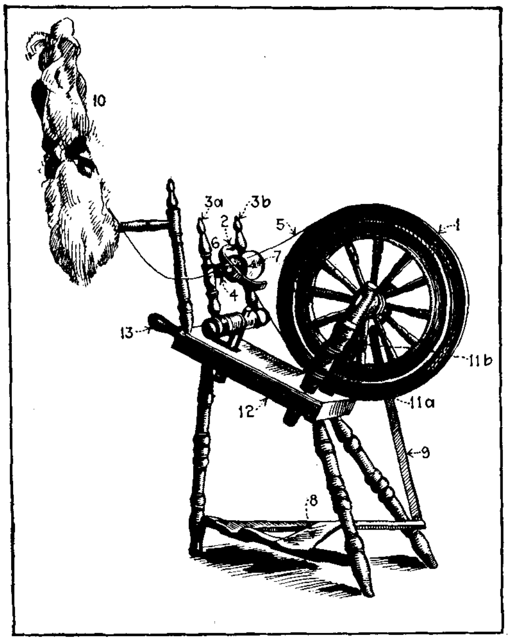

Fig. 16.—The Flax Wheel.

let out as the spinner wished, according to her ability or her desire for fine yarn. The slower movement of the bobbin caused the yarn to wind upon it. The bobbin or reel fitted loosely on the spindle, and was slipped on it by removing the pulley at the end of the spindle. The bobbin had also a groove or pulley at one end of it, around which one of the cords from the wheel was placed. V. A band or soft cord (5) was passed twice around the wheel; one part went over the grooved pulley or wharve on the spindle, and the other over the pulley on the bobbin, causing them to revolve with the wheel. VI. A handle (13) regulated the tension by turning it either backward or forward, thus moving the standard on which the spindle and other parts revolved, and tightening or loosening the band. VII. Underneath the framework was the treadle (8), connected with the wheel by means of a rod (9), which was attached by a crank to the iron bar through the hub of the wheel, and was tied to the treadle.

The Motion of the Saxony Wheel was continuous, that is, the drawing, twisting, and winding occurred simultaneously, and not as in the great wheel in two divisions, requiring the stopping of the wheel and backing off of the thread on the spindle before winding began.

The Method of Spinning on the Saxony Wheel. — The flax was carefully prepared beforehand in order to have the fibers parallel and untangled. The spinner laid the flax carefully down on a flat surface, and turned the distaff in it until it was evenly covered. She then tied a ribbon loosely about it to keep it in good order, and placed the distaff on the standard. The fibers were now in good condition for drawing steadily down as many or as few as she desired. The spinner sat beside the wheel with her foot on the treadle, and by means of the connecting rod gave motion to the wheel. The double band caused the revolution of the spindle and flyer as well as the bobbin through the wharves on each. She drew the threads down from the distaff with her right forefinger and thumb until they reached the eye of the spindle. The flax passed smoothly under her second, third, and fourth fingers as she held it lightly between the first finger and thumb, which she slightly turned toward her as the thread was drawn down. She used her left hand to open up the mass of fibers next to the distaff, making them into a wedge shape with the narrow end running toward the right hand. She slightly twisted them, and threaded the yarn thus made through the needle's eye in the spindle, brought the thread over one of the hooks of the flyer and fastened it on the bobbin by means of a thread which had been left for this purpose. Beginners often found it difficult to keep the wheel revolving smoothly while drawing the flax evenly from the distaff to the spindle. It took time to become a good spinner. The threads of flax were kept moistened by the spinner in order to make a tighter and smoother twist. The spindle, the iron bar on the large wheel, and the crank connected with the treadle were kept well greased.

The Saxony wheel was more complex than the great wheel. The flyer (Fig. 17) on the spindle by which the thread was twisted (said to have been invented by Leonardo da Vinci) was a great step in advance of former spindles, and is utilized in power spinning even to the present day. The continuous motion of this wheel made it possible to spin more and stronger thread in a given time than had any previous invention. The bobbin revolved at a different speed from the spindle, consequently it was possible to wind up the yarn as it was being spun. The flax wheel was improved upon in various ways, and two spindles were later used on it at one time, enabling expert spinners to double the output.

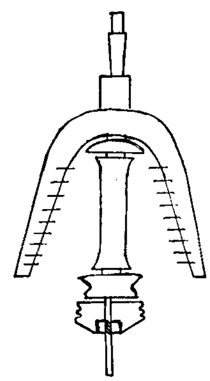

FIG. 17.—DETAIL OF FLYER.

Hand and Machine Carding. — The opening up, combing, or carding of raw fiber is probably as ancient as the art of spinning. The first cards or combs were evidently the fingers, with which the matted mass was opened, dirt and knots were pulled out, and the fibers were laid in a soft, open lap. A device for aiding the hand was later made of wood or bone, the shape being like the outstretched fingers. This instrument was succeeded by two flat pieces of wood covered with skin (Fig. 18), through which teeth or thorns protruded. The fiber was laid between the teeth of the two combs, and combed or carded thoroughly. Such cards are still in use by primitive people, and also in some modern factories, where they are used for blending wools and trying out colors. The Navajo Indian woman of Arizona uses cards to comb her wool. They are made like the primitive ones, but the flat surfaces are now covered by card

FIG. 18.—HAND CARDS.

From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

clothing (bent wires closely set together in leather or rubber). After the Indian woman prepares her raw wool, — always a very necessary part of successful carding, — she sits down on the ground and spreads a small quantity of wool on one card, which she holds face up with the left hand. The other card she holds with the right hand, having the card clothing down. She firmly presses one card on the other, and draws toward her the one in the right hand, thus combing through the fibers on the other card. By repeating this process she finally has the wool in a clean, fluffy mass. When the wool is sufficiently open and free from dirt she lays the lap on the back of the left card, and makes it into a roll or sliver with the back of the other. With these rolls she spins her yarn.

When the demand for more rapid spinning came there was naturally an equal demand for better and more rapid carding, for good spinning depends upon it. The problems before the inventors of the eighteenth century were to accomplish the work of the hand cards by mechanical means at greater speed, and to make a continuous sliver instead of short pieces. They wished to do this with the minimum injury to the fiber and with the least possible waste. It cannot be said, however, that the modern carding engine, wonderful as it is, works with as little bad effect on the fibers as did the hand cards.

When Lewis Paul in 1748 discovered that carding could be satisfactorily done by the use of revolving cylinders covered with wire clothing, he gave the principle of modern carding. James Hargreaves invented an improved cotton carder in 1762, which had more than one cylinder rotating in contact with the cotton. Richard Arkwright also invented one which he used in his own mill at Cromford. Until 1772 the fiber was fed by hand into the carding machine, but John Lees or Leigh of Manchester invented an apron feed, which saved the labor of one worker and facilitated the process by making it continuous. At that time the slivers received from the carder were in short pieces like the rolls from the hand cards. Arkwright made an invention by which the cotton was fed in a wide lap to the machine, which carded it and passed the lap thus made to a funnel, which contracted it into a sliver. He also invented a doffer or stripper to remove the sliver from the machine. The doffer was a helpful invention; it is claimed by both Arkwright and Hargreaves.

These inventions led to great changes in methods of manufacture. By 1774 all of the principles of modern carding were in use, — the continuous carding surface, the continuous feed, and the continuous doffer. In the modern carding engine an enormous number of fine teeth come in contact with the fiber; the object sought — of cleaning, opening, and laying the fibers parallel — is accomplished, but the process is a severe strain on them. Good carding often requires many previous processes of cleaning and opening, all of which have an effect on the strength of the fibers. On account of differences in the characteristics of raw materials, the processes leading up to carding and the work itself differ. Silk and flax are not carded, although the latter undergoes a similar process called hackling.

The revolving flat card (Fig. 19) is used extensively in the United States for cotton. It has a cylinder about fifty inches in diameter and forty inches in width, called a swift, which is covered with card clothing, having about six or seven hundred steel wire teeth per square inch, amounting in all at times to three or four million. The teeth are turned in the direction of the movement of the cylinder. They are fastened in a leather, rubber, or cloth foundation, similar to the hand cards. In the process of carding, a large roll of partly cleaned cotton is placed in front of the machine. A revolving small roller takes the end of this sheet of cotton and delivers it to the "licker-in," which in its revolution brings the cotton in contact with the big cylinder or swift, and the teeth catch the cotton and carry it on. Flat bars on an endless lattice above the swift are covered with card clothing, and in rotation press their teeth into the cotton which is on the cylinder. The contact of these slowly moving flat bars with the revolving cylinder is like the contact of the two hand cards; the cotton is thus combed and cleaned, and the poor fiber is carried away by a stripper. This rough, broken fiber is used for cheaper classes of goods, having machinery especially adapted to it. The impurities drop through to a box under the machine. The revolution of the swift carries the good carded cotton to a point directly opposite the licker-in, where it is stripped off by another revolving cylinder, called the "doffer cylinder," the teeth of which are so set that they take the cotton from the big cylinder or swift. An oscillating knife or comb, the "doctor knife," strikes the cotton from the doffer cylinder, and the soft lap is then delivered to a funnel or to two rolls which contract it into a ribbon or sliver and deliver it to a can. The great cylinder or swift often moves at a rate of 150 to 200 revolutions a minute. The doffer comb strikes the cotton about a thousand times a minute. The

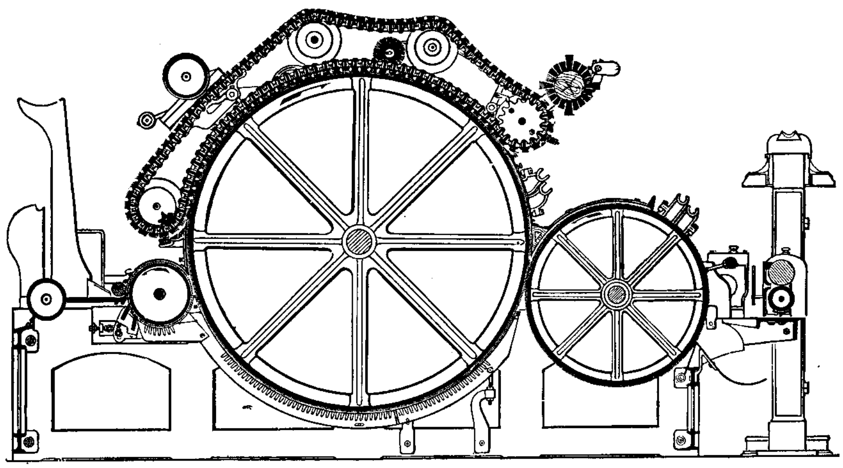

FIG. 19.— REVOLVING TOP FLAT CARD.

Courtesy of the Whitin Machine Works.

card for wool does not aim to lay the fibers parallel, but simply to open them into a soft mass. A series of small cylinders, covered with card clothing, working over the top of the swift, take the place of the flat bars in the cotton card. These rollers or cylinders are in pairs called workers and strippers and alternately press the wool on the teeth of the swift and remove it again, thus opening the fiber. Three cards in a train are in general use in the wool industry. (See Chap. VI.) The fiber passes from one card to another in a transverse direction, to overcome the inclination to parallelism. The card in use in the worsted industry differs from the train of cards required in the wool, but the principles remain the same. The rapidity of movement in the swift depends upon the length of staple of the fiber. In the wool card the final stripping roller is called the fancy. It is larger and has longer teeth than the others, in order to lift the carded wool from the teeth of the cylinder, that the doffer may carry it off. The speed of movement in the various cylinders depends on the requirements of the raw material.

Modern Spinning Machines Developed from the Principles of the Wheels. — In England about the middle of the eighteenth century pressure for more rapid production of cloth, especially of cotton cloth, began to be felt. Suffering from poverty had lessened and more comforts were demanded. The subdivision of industry had increased in the towns, and as women no longer spun and wove in every home the demand for textiles was insistent. There was scarcity of yarn for weaving, for many of the spinners were not capable of making warp yarn. Wool and flax heretofore had been the staples, but the introduction into England of cotton fabrics from India led to a demand for the spinning and weaving of that fiber. Some inventions were made, but little was thought of them at first, therefore the names of the first inventors and the dates of their inventions were not carefully preserved and are even now uncertain. The supply of yarn and the ability of the weavers to turn out cloth were about equal when John Kay of Bury invented his fly shuttle and picking stick (see Chap. IV), thereby increasing fourfold the output of the loom. This was followed by a patent of Robert Kay, son of John Kay, of the drop box (see Chap. IV), which also saved the weaver's time. These inventions brought the capacity for weaving far ahead of the supply of yarn. Pressure was brought to bear on the spinners to meet the situation, by (1) finding a mechanical way of spinning a number of threads at one time by keeping more spindles revolving, and (2) some automatic means of drawing out the fibers. John Wyatt of Birmingham is generally conceded to have been the first to suggest a way of spinning thread without the use of fingers. His patent was taken out in 1738 in the name of Lewis Paul, his partner. In his machine he uses the flyer of the Saxony wheel for spinning, but probably he had an entirely new and brilliant idea in the use of drawing rollers to attenuate the yarn. This latter principle is important in power spinning. Richard Arkwright later used this principle in his water frame, but gave no credit to either Wyatt or Paul, and is generally given credit for the invention.

In 1764 or 1767 James Hargreaves, a spinner and carder, living in Blackburn, Lancashire, invented a spinning frame

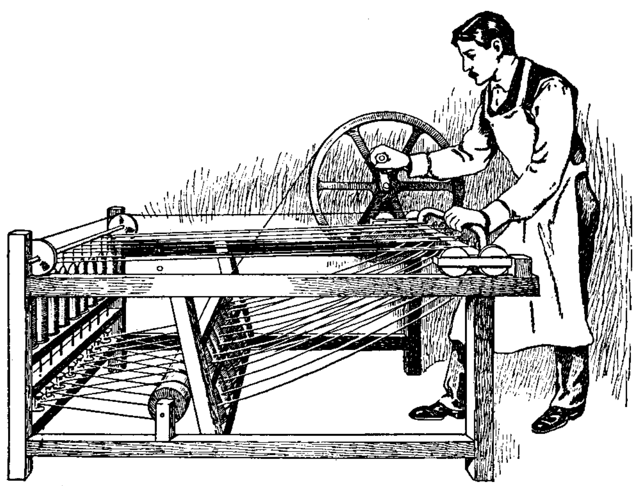

FIG. 20.—HARGREAVES' SPINNING JENNY.
From Robinson and Beard's *The Development of Modern Europe*, by courtesy of Ginn & Co.

(Fig. 20) which was the progenitor of the modern self-acting mule. (See Fig. 22.) His idea was evidently taken from the principle of the great wheel. For power he used one hand to control a traveling carriage, and the other to turn a wheel by means of a crank. The wheel was connected by a band with a cylinder under the framework, and bands went from the cylinder to the pulley or wharve of each spindle, thus setting them in motion as the wheel turned. This machine spun from eight to eleven threads at once. It was a great invention, but the fibers were not parallel, and the yarn was too softly twisted to be used for warp. The pictures now seen of the machine have improvements over the original invention. The important principles of Hargreaves' spinning jenny were (1) a number of bobbins of roving (the last step in the preparation of yarn previous to spinning) were placed vertically in a creel under the frame; (2) the yarn from these bobbins passed through a holder and across to the spindles. The holder was so made that it could keep the threads fast or let them slip, and (3) a carriage which could be moved back and forth on the framework so that the holder could be drawn away from or moved toward the spindles. When the carriage was near the spindles the roving was caught in the holder and fastened to the tip of the spindles, and was attenuated by drawing the carriage away from the spindles. In the meanwhile the stretch of roving was twisted by the revolution of the spindles by means of the wheel. When the carriage reached its farthest point on the track it was stopped, but the spindles were kept turning until the yarn was sufficiently twisted. The wheel was then stopped, and the carriage was backed slightly to allow guide or faller wires to back off the twisted thread from the end of the spindles, as was done in the great wheel. The carriage was now pushed back toward the spindles while the length of spun yarn was wound up. Thus Hargreaves' jenny repeated the intermittent motion of the great wheel, for the attenuating and twisting were done in one motion, and the winding in another. When one length of yarn had been spun, the bar on the holder was loosened, another length of roving was drawn from the bobbins into the holder, and the work of drawing and twisting was repeated. This machine was used widely, but Hargreaves had little use of his patent, which was taken out in 1770, for the hand spinners were infuriated, and persecuted the inventor for taking away their work. He was obliged to flee from his home on account of the tumult. He deserves to be remembered as one of the fathers of the modern industrial world, for he made cotton spinning possible, and thus brought a cheaper fabric to the poor of England. Credit for this invention is given by some to High of Leigh.

The spinning jenny was known to Richard Arkwright, a clever barber of Preston, who wandered about the towns of

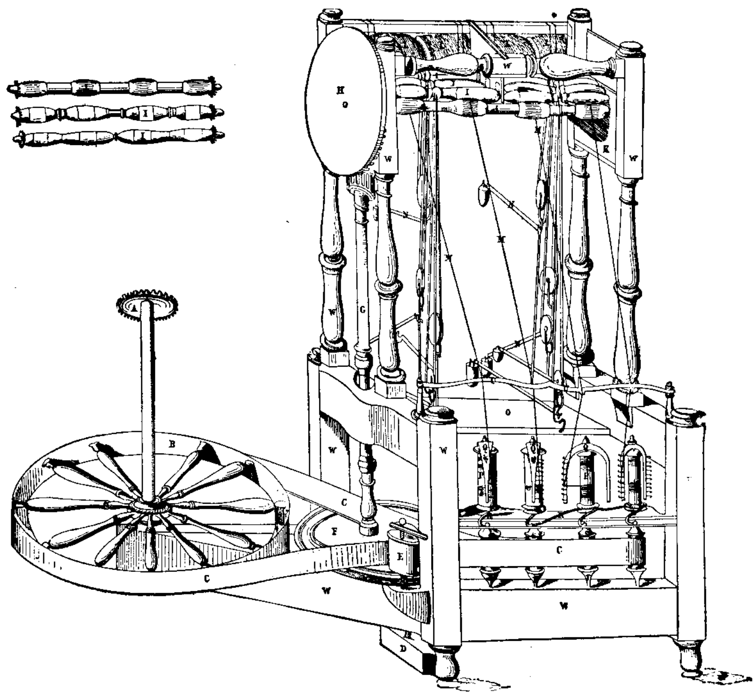

FIG. 21.—ARKWRIGHT'S WATER FRAME.
From Barker's *Textiles*, by courtesy of Constable & Co., London.

England in pursuit of business. He continually heard of the need of yarn and cloth, and probably improvements in devices were talked over with him, and new appliances shown him. About 1768 he brought out a machine founded on the principle of the Saxony wheel. It had an upright frame, a continuous motion, and the spindle and flyer of the Saxony wheel placed vertically (Fig. 21). The roving passed through twin drawing rollers and was attenuated before being twisted. It is probable, though not proven, that he had seen this in the machines of Wyatt and Paul. He received much credit for his invention, but is thought to have been a greater business man in forwarding the ideas of others than original in inventions of his own. His ideas of factory organization are not yet obsolete. He is, in any case, worthy of honor for what he has given to us. The principle of his machine is as follows: The roving was attenuated by means of a couple of twin rollers placed one behind the other. The first two rollers which received the roving ran rather slowly, but the two rollers ahead moved more quickly. Hence the fiber was caught, drawn, and laid more nearly parallel. After the roving, now of the required thickness, left the rollers, it was twisted by the flyers of the spindles and wound on the bobbins. Arkwright probably gave us the reciprocal vertical movement of the spindle. His first mill was built at Cromford in 1771, where he installed his own carding and spinning machinery. So greatly was his work appreciated that he was knighted. His machine was too heavy to be driven by the human hand, hence horse or mule power was used, and later water power gave his invention the name of the water frame, or water twist frame. The homes of that time where most of the spinning had been previously done could not provide sufficient force, consequently small factories sprang up where the Arkwright spinning frame spun the yarn for those having private looms or for groups of manufacturing weavers. Steam power was applied to it in 1790. The use of drawing rollers is the great basis of modern spinning.

Another inventor of note of this period was Samuel Crompton of Bolton. He was a textile worker, and a capable man. He felt the need of a greater supply of warp yarn in his daily work. His invention in 1779 was a spinning frame which combined the good points of the machines of both Hargreaves and Arkwright. From Hargreaves he took the upright spindle frame, but placed it on the moveable carriage. (In Hargreaves' machine it had been attached to the back of the main framework.) From Arkwright he took the idea of drawing rollers and placed them where Hargreaves had his spindles. It is believed by many that Crompton invented the drawing rollers for his machine, and that he had never seen or heard of the Arkwright patent. Crompton placed the roving or slubbing in a creel behind the spindles. He patented his machine, calling it the mule spinning frame. It proved to be a wonderful machine, and has been the basis for one of the most useful spinning frames of the present day — the self-acting mule. Crompton was not only an inventor himself, but he knew how to take advantage of the inventions of others and use them in his own way. At that era before steam power was utilized, Crompton's mule was of more use than either Hargreaves' spinning jenny or Arkwright's water frame. Many other inventors made important additions to these inventions. The use of steam for power, and Whitney's cotton gin, both of which came at the end of the eighteenth century, gave a tremendous impetus to cotton spinning, and the inventions of Roberts in 1830 gave the world the modern self-acting mule, which was a triumph of skill and automatic action.

The following dates mark important eras in the development of modern textiles: —

1. Distaff and spindle, from the dawn of history to about the fourteenth century.

2. Spinning wheels, from the fourteenth to the eighteenth century.

3. The great eras of invention: (*a*) Improvements in spinning and weaving, (*b*) the use of power other than the hand, and (*c*) the modern factory system.

The beginning of modern spinning, carding, and weaving came principally from such men as the following: —

JOHN WYATT, Birmingham. First thread spun without fingers, and the use of drawing rollers, 1738.

LEWIS PAUL. In connection with Wyatt, carding, revolving cylinder, 1748. (Claimed by Hargreaves.)

JOHN KAY. Fly shuttle, 1738; improved in 1750.

ROBERT KAY, the son of John. The drop box, 1760.

HARGREAVES. Spinning jenny; the spinning of a number of threads at once, 1764–1767.

ARKWRIGHT. Water frame (upright), 1768; the principle of rollers; doffer comb.

CROMPTON. Mule frame, combining Arkwright's and Hargreaves' ideas, 1779.

LEES or LEIGH. Apron feed, 1772.

CARTWRIGHT. Power loom, 1789. Application of steam to Arkwright's frame, 1790.

ELI T. WHITNEY. Cotton gin, 1794.

ROBERTS. Self-acting mule with quadrant, 1830.

The half century from 1750 to 1800 was one of tremendous issues. On account of the inventions capital became more important than labor, factory towns took the place of farming villages, large numbers of women heretofore working in the homes had to work in the factories, markets were extended all over the world to make use of the larger output from machinery, and society to meet these conditions had to be almost entirely reorganized.

At first the industries of spinning and weaving were separate. Little factories began to spring up where water power was good. When steam power was used, spinning and weaving were often combined to save expense. But about the middle of the nineteenth century, so much capital was required to combine the two that they were again separated, except in very large plants.

Modern Spinning Frames. — The principles of modern power spinning follow closely the inventions of Hargreaves, Arkwright, and Crompton. These men in their effect on the development of our factory system may be said to have been among the principal instruments in bringing forward the industrial and social problems of the present day. One girl now probably spins twelve hundred times as much in a day as was done with the old wheel. The difference between the old and the new is not in the principles employed, but in the mechanism which is used to take the place of the hand, *i.e.*, the belts, pulleys, levers,

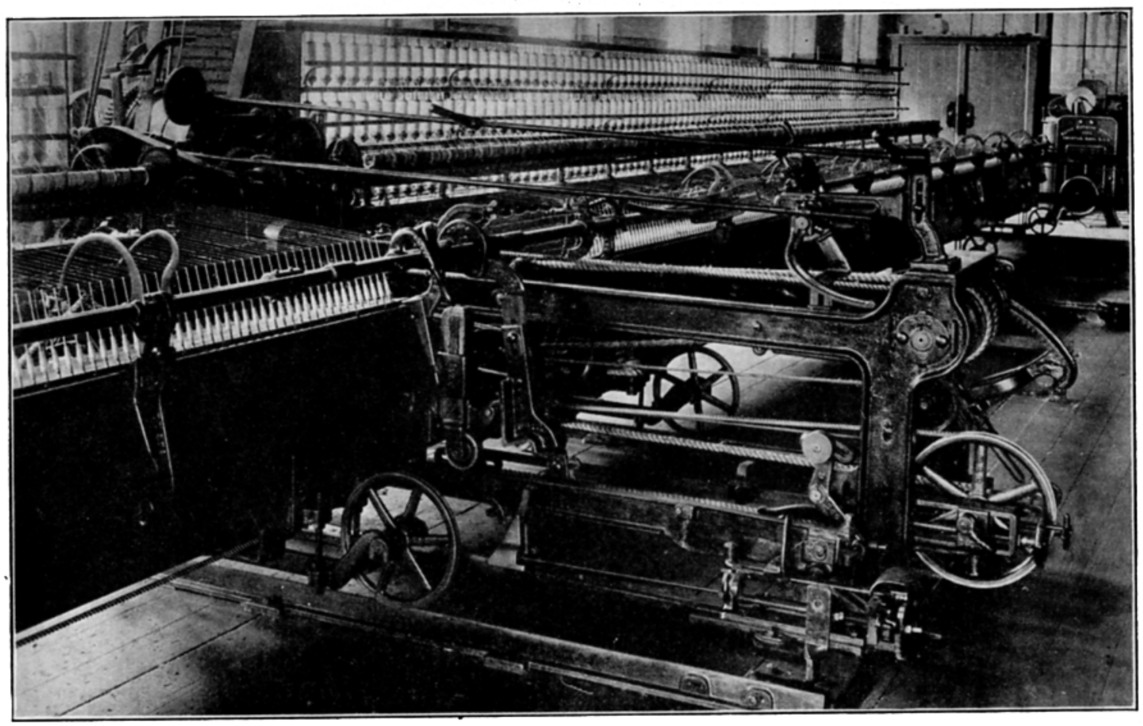

Fig. 22. — Mule Spinning.
Courtesy of the Mason Machine Works.

wheels, gears, springs, chains, and cams, which automatically handle a thousand spindles at once, where the hand controlled one. True spinning is in reality the final process of twisting, but the term spinning is used to cover all of the preparatory steps as well. Before the final spinning the twisting is only sufficient to keep the attenuated fiber from breaking apart. The final process before true spinning is called the roving. The final spinning may be done by the mule (Crompton's patent), or by a ring spinning frame on the order of the upright spinning frame (Arkwright). Both machines may be used for tightly or loosely twisted yarns, but the mule is better adapted to the softer yarns, and the upright frame to the closer twisted yarns.

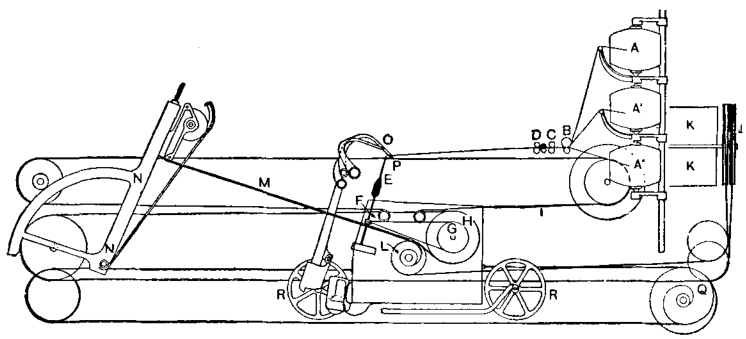

FIG. 23.—DETAIL OF MULE.

From Barker's *Textiles*, by courtesy of Constable & Co., London.

In the present day the true spinning machines are preceded by others which are more or less similar in method, but they only prepare for the final twist. The principle of rollers is used for drawing and attenuating the fiber, and the twisting is done not only by the flyer but by other methods. The modern mule spinning, which has developed from Crompton's mule, is more complicated than ring spinning, which followed Arkwright's upright frame.

Mule Spinning — Intermittent Motion (Fig. 22). — The essential features are as follows: The bobbins of roving are placed in a creel in the back of the machine. The roving

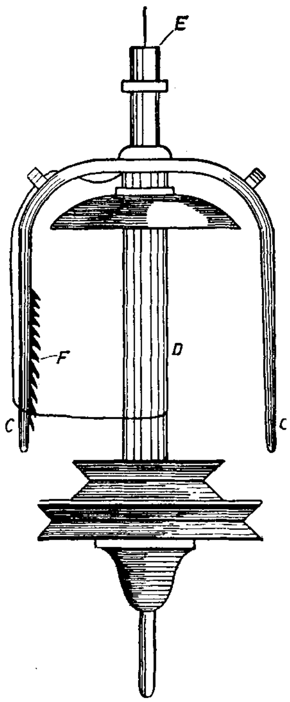

FIG. 24.—FLYER.
From Barker's *Textiles*, by courtesy of Constable & Co., London.

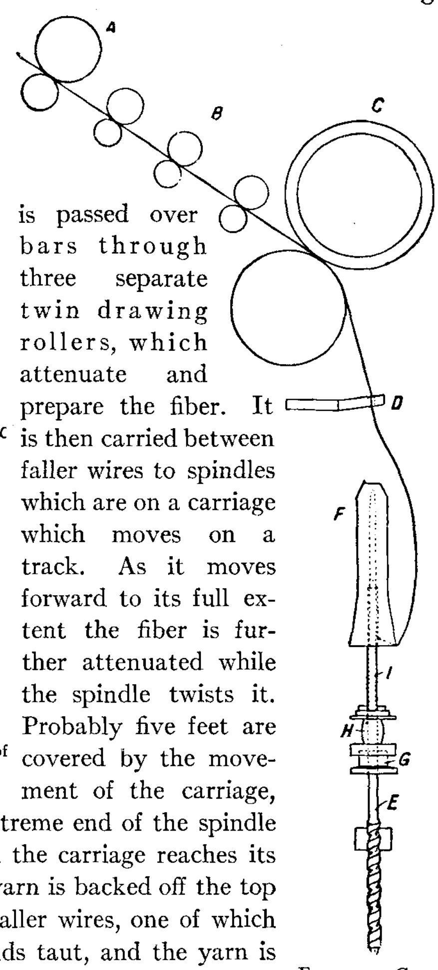

FIG. 25.—CAP SPINNING FRAME.
From Barker's *Textiles*, by courtesy of Constable & Co., London.

is passed over bars through three separate twin drawing rollers, which attenuate and prepare the fiber. It is then carried between faller wires to spindles which are on a carriage which moves on a track. As it moves forward to its full extent the fiber is further attenuated while the spindle twists it. Probably five feet are covered by the movement of the carriage, the yarn being at the extreme end of the spindle for this purpose. When the carriage reaches its limit, it is stopped, the yarn is backed off the top of the spindle by the faller wires, one of which guides and the other holds taut, and the yarn is wound up on the spindles as the carriage returns to its place at the back of the mule. As a consequence the action is intermittent, as in the great wheel (Fig. 23). The spindles are placed at an angle of fifteen degrees, and each is provided with a wharve, whorl, or pulley by which it is revolved, a band around it passing to a driving cylinder. The mule is a complicated machine, and requires skilled attention. Men are usually in attendance. The machine has to be adapted to differences in fiber, as between wool, worsted, and cotton. High counts of yarn may be spun on the mule.

Ring Spinning — Continuous Motion. — The principle of ring spinning has largely taken the place of the flyer spinning as found in Arkwright's patent. Following the Arkwright spinning frame came a series of inventions to improve the spindles. The upright frames look much alike. The drawing rollers were satisfactory and are found about the same, whether the flyer, ring, cap, or top principles are used for the spindles. A throstle frame (still used for making roving) followed Arkwright's patent, and combined some features of Hargreaves' jenny with Arkwright's water twist, giving a new spindle, but it is seldom seen now in true spinning. The flyer (Fig. 24) principle is seen in the bobbin and fly frames, used to prepare the rove (slubber, intermediate, and roving) in cotton spinning.

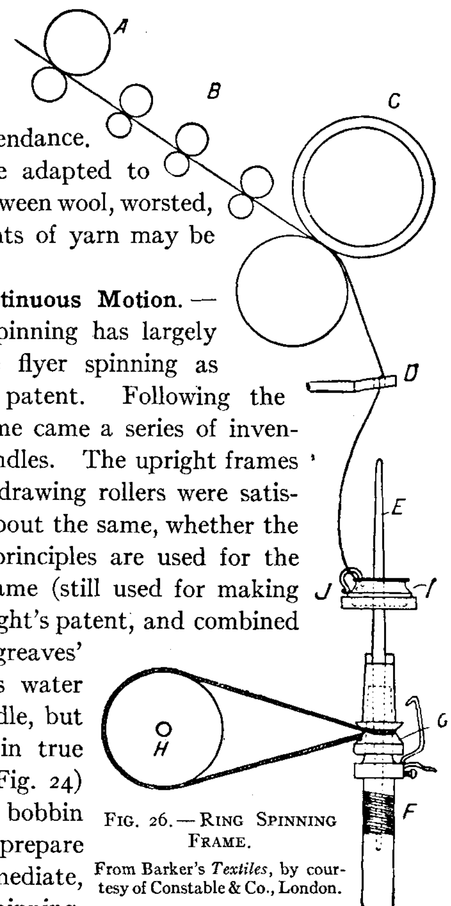

FIG. 26. — RING SPINNING FRAME.
From Barker's *Textiles*, by courtesy of Constable & Co., London.

The twist depends on the relative speeds of the bobbin and flyer. The spindle has gradually been made more free in its motion, and runs more loosely in its bearings, which makes it steadier. Cap spinning (Fig. 25), used much in cotton spinning, utilizes this idea, and gives the spindle as much freedom as a spinning top, which running at full speed balances itself. Cap spinning is used in spinning worsted yarns, the principle at base being a stationary spindle with a stationary cap and a revolving bobbin. The latter has a whorl on it, and a band connected with the driving shaft makes it revolve. The yarn comes from the rollers above, the bobbin moves up and down, and the end of the cap keeps the yarn evenly winding on the bobbin.

In ring spinning (Fig. 26) the yarn is twisted immediately on leaving the rollers. In spinning frames there are usually

FIG. 27.—DETAIL OF RING.

two rails. In the lower the spindles rest, and through the higher, called a bolster rail, the tops of the spindles pass. In ring spinning there is a third rail. This rail moves up and down the spindle, causing the yarn to wind evenly. A series of rings (Fig. 27), each with a flange, are fixed on the rail, and move with it. The front of each spindle goes through a ring, but does not touch it. A traveler, which is a crooked piece of fine wire, is sprung on the flange. It can move easily, but cannot come off. The ends of the yarn come through the rollers and each passes through a traveler and is fastened on a bobbin which is on the spindle. The spindle and traveler revolve rapidly. The latter is held back slightly by the yarn and consequently winds the yarn on the bobbin. A traveler makes as many as 10,000 revolutions per minute. Separators of metal are often used between the spindles to keep the threads from interfering.

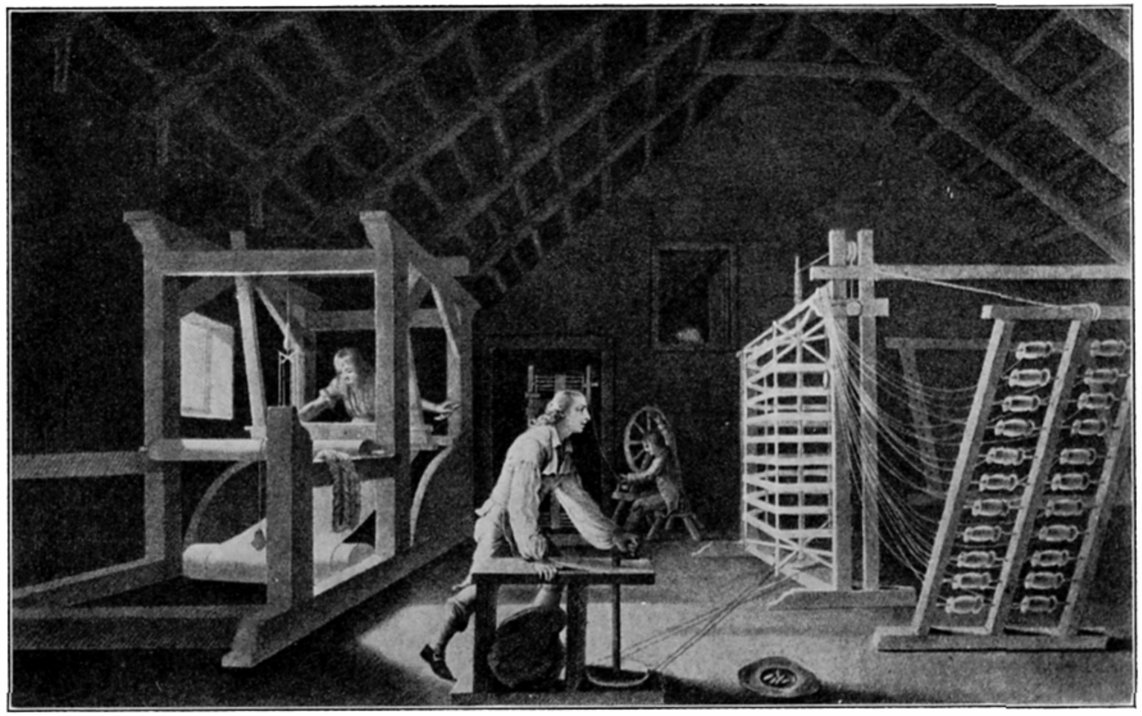

FIG. 28. — AN ANCIENT WEAVE ROOM.

CHAPTER III

HAND WEAVING

WEAVING is the interlacing of two lines of threads crossing each other at right angles. (See Fig. 4.) Plain or pattern effects are made according to the manner in which the threads are interwoven. The threads running the length of the cloth are called warp, or ends, and are set up first in the loom. Those that intersect and run across the warp are called woof, weft, pick, or filling. The filling threads which bind in the warp threads at either side form the selvage (Fig. 29).

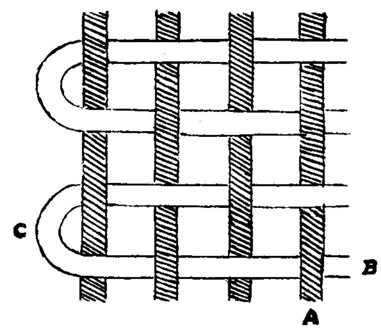

FIG. 29.—DETAIL OF WEAVE.

A, Warp or ends.
B, Filling, woof, weft, or picks.
C, Selvage.

Weaving is one of the most ancient of the arts. Its development has called forth and still requires a high order of mechanical ability. Marvelous results in fineness of cloth and beauty of design were attained in it even when it was in its infancy, with few devices to aid the hand, and when to make one rug required untold labor. Even modern machinery cannot outdo the handwoven materials from various parts of the world. At first women were the weavers, but since the industry has passed from the home they are no longer preëminent in it, though they still work in the textile factories. It is said that one fifth of the working world is now occupied with weaving, its allied arts, and the distribution of the products of the industry.

Our present knowledge of the beginnings of weaving comes (1) from the work of nations which are now in primitive conditions and whose work we can watch, such as the natives of the

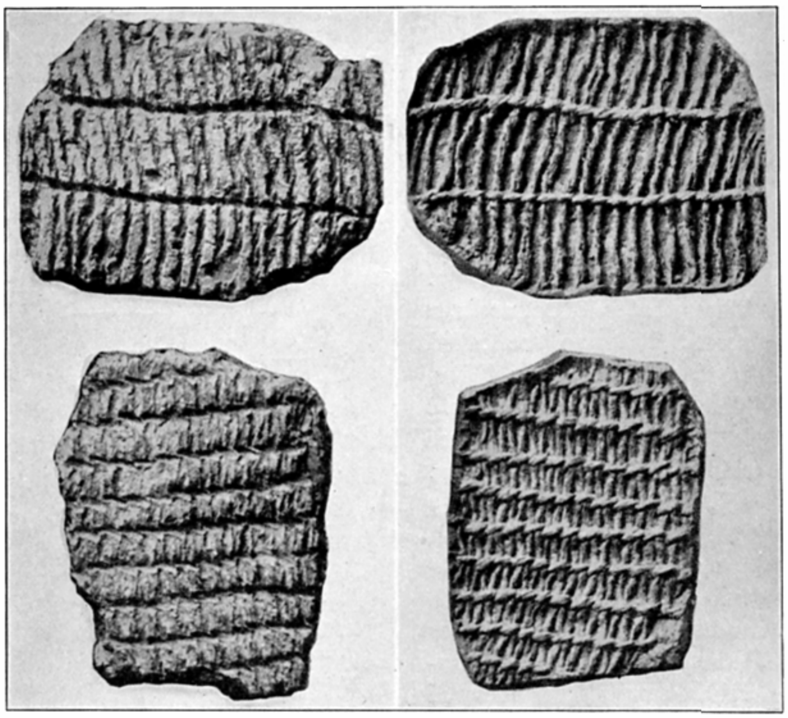

FIG. 30.—TEXTILE-IMPRESSED POTTERY.

A. Pottery. *B*. Weave used.

Philippine Islands, the American Indian, and African tribes; (2) from early pottery, which was frequently decorated with a textile design, and shows clearly that woven cloth was laid upon it when it was in a moist state (Fig. 30); (3) picture writing on tombs; (4) mats, rugs, and cloth which have been preserved in tombs. These ancient materials show the art from the coarsest mat weaving to the finest cotton and linen fabrics, with often the most intricate designs in various colors woven upon them.

Principles Underlying Weaving. — A knowledge of the principles of weaving is found among almost all primitive people, no matter how savage, and their first steps toward an adequate loom seem strangely similar, when it is remembered that there was often no communication between nations. There were three principles developed, and these same three are the important ones in modern power weaving: (1) *shedding*, or the raising of the warp threads as needed; (2) *picking*, or the throwing across of the filling; (3) *battening*, or the driving up of the filling. Various devices were invented to facilitate these motions. Weaving was done at first by the hand alone, rushes being laid lengthwise on the ground and lifted alternately, to allow the woof or filling to be inserted across them, and the fingers pushed the filling into place. One of the first inventions was a way of holding the warp stretched, that the threads of it might be raised more easily for the insertion of the filling. The early looms (see Fig. 3) were usually vertical, and had a heavy wooden bar or beam at the top to hold the upper ends of the warp, and stone weights tied to the lower end of each thread, thus keeping the warp taut. The beam was suspended in a framework, or between trees. Some nations placed bars at each end, which were forerunners of the warp and web beams of the modern loom. To accomplish a more rapid raising of the warp threads sticks were inserted alternately in the sheds, to indicate the path of the filling, a simple device which led finally to the harness of the modern loom. (See Fig. 47.) To take the place of the fingers for throwing the filling threads across the warp, a stick was used on which the filling was wound; this later became the shuttle containing its quill of yarn, and the shuttle race. (See Fig. 46.) As a means of widening the shed for the insertion of the filling, and later battening it up, a sword or batten (See Fig. 34) was used, which served both purposes. The lathe or sley of the modern loom, with its reed, has developed from the early sword.

Primitive Looms. — Many kinds of looms were invented: (1) the upright or vertical, such as the Navajo Indian loom or some forms of the tapestry loom; (2) the horizontal loom, like those of the Moros of the Philippine Islands, and of the Zuni and Pueblos of America, a form also seen in the hand loom of colonial days and in the power looms, and (3) slanting looms, such as

FIG. 31.—CHILCAT BLANKET.

are found among the rug makers of the East. A simple form of loom is found in British Guiana, in which the lower end of the warp is rounded by the use of a flexible reed, and the upper bar is straight. As the warp threads are put in they widen slightly. A rod laid across the warp is attached to alternate threads by a cord and is used as a simple means of drawing these threads out while leaving the others down, thus forming the shed. A slender stick on which some yarn was wound was used for a shuttle, and a wider stick with a flat edge beat the threads together. Color was introduced by hand, the design being thus a variety of tapestry weaving on stretched threads. The Navajo loom has similar devices. The beautiful Chilcat blanket (Fig. 31) used for ceremonial purposes and woven by the Tlinget Indians of northwest United States, is rounded, and heavy weights held the warp threads in place while the weaving was in progress. It was woven of goats' wool combined with bark, and had a marvelous conventionalized design of a whale. Few devices were used by the weaver.

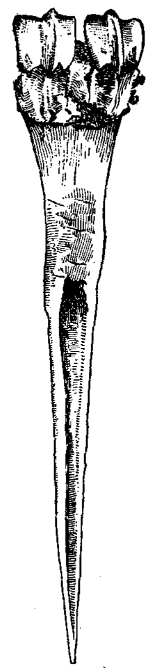

FIG. 32.—BONE AWL.

Tools of various kinds were invented by different peoples to assist in the making of cloth, such as knives to split material, which took the place of the teeth of the worker; gauges to measure distances, which replaced the finger nail; awls to assist the fingers in fine work, and act as needles (Fig. 32), and combs to help the fingers in driving home short sections of filling.

At the time of the discovery of America, the art of weaving was well advanced among the inhabitants. The Zuni Indians invented an interesting heald shaft or heddle for making the shed. It consisted of a series of small flat sticks held in a frame-work, with holes in the center of each stick, and spaces left between the sticks. (See Fig. 35.) The first warp thread was passed through a slit between sticks and the second through a hole in a stick, the third through a slit, the fourth through a hole, until all the warp threads were disposed of, every other one being through a slit and the alternate ones through the holes. The shed was formed by raising or depressing the heddle, thus threads were alternately brought up or down, through which the filling was passed and battened up. This form of heddle is on the order of those used in the modern power loom (Fig. 47). Heddles of similar construction are found in many parts of the world. The Esquimaux made one of bone, and the European carved one from wood. Our colonial women used a similar heddle in their tape weaving.

The Navajo women are still weavers. Beautiful rugs were once woven of the wool of the native sheep, dyed or undyed, and characteristic designs upon them had been in use for centuries. Unfortunately the demand for a cheap rug is injuring their art. Few buyers understand the value of these old rugs, and consequently are unwilling to give an adequate price for them. The better grade of rug took sometimes as long as a year to weave, but the present one is frequently made rapidly and poorly, with a cotton warp and commercial wools for filling. Cheap dyes and poor designs are used. In fact, these rugs are even copied on power looms and sold in large quantities. The real Navajo rug has the hand spun yarn prepared for the loom by winding it around two upright sticks which are set apart the length of the rug. The threads are wound on the sticks transversely or spirally to form a crossing, until there are sufficient for the width of the warp. A stick is then slipped through the warp at either end, which secures the lease or crossing — thus every other thread can be traced. The lease is vital in both hand loom and power weaving. The Navajo woman sat on the ground to do her work. The loom (Fig. 33) consisted of a framework made usually of two poles and two beams. The poles were forked at the top and stood upright; the beams were lashed across at the top and bottom. At each end the warp was wattled (see Fig. 2) in and out by special threads, which kept it from slipping. It was then stretched between two other poles the width of the rug. The poles were lashed to the beams. As the warp hung taut the lease or crossing of the threads could be clearly seen, for every other thread was slightly forward of the alternate ones. By slipping sticks into these sheds they were accented. A simple harness was made by laying a long rod across the warp threads, fastening a piece of strong yarn to the rod, and in succession catching the yarn around each back thread in the lease and then around the rod. When all the back threads were thus connected with the rod, they could be drawn forward at one time, making a distinct shed. Through this the sword was thrust and turned over to make a wider opening of the threads, while the filling was inserted. A stick had been placed in the

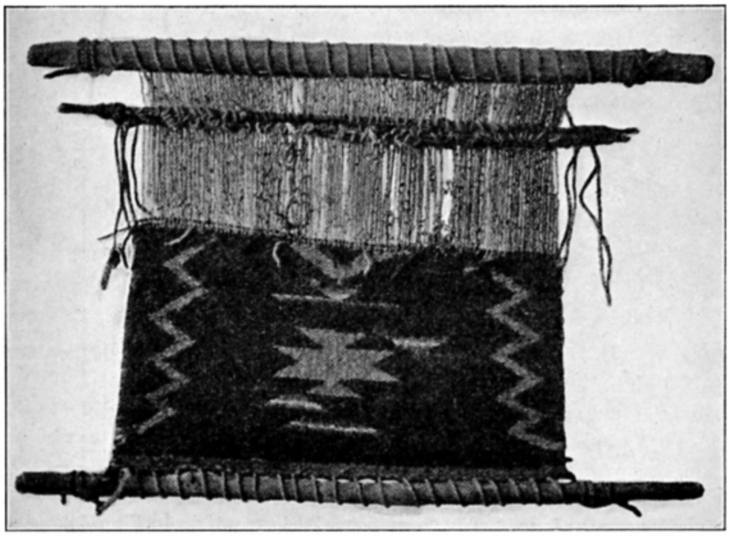

Fig. 33.—Navajo Loom.

alternate shed, which preserved it. As the threads of this shed were forward in the crossing they were easily distinguished at any time. When this forward shed was to be used the sword or batten was placed in it and turned to its full width, as in the shed attached to the harness rod. The weaver usually began to work from the bottom up, but some worked from both ends, using a needle for the final weaving. She alternately opened the sheds, turned her batten in them, put her filling across, and drove it home with the batten by turning it flat and drawing it toward the finished weaving. She used a rude wooden comb to drive the filling home when she wished to batten in a few threads at a time, in order to make a design. If she needed to let down the warp threads, she loosened the lashings at the top, lowered the pole with the attached warp threads, wound up the finished weaving on the lower pole and made all tight again. When different colors were needed she used separate balls of colored yarn, white, gray, and black being favorites

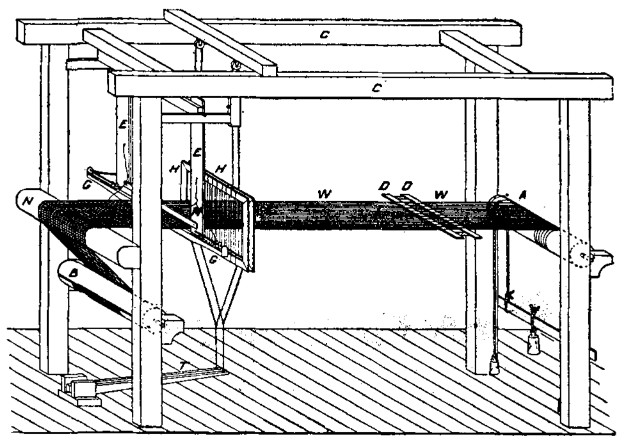

FIG. 34.—HAND LOOM.

From Watson's *Textiles and Clothing*, by courtesy of The American School of Home Economics.

with the Navajos, though red and yellow were also used. The Navajo's work is really tapestry weaving, for the design is put in by the fingers as desired, and is not dependent on the harness. When she had finished with one color, she allowed the roll of yarn to hang suspended while she took up the next color. The Navajos conduct their whole industry, growing the sheep, shearing, cleaning, carding, spinning, dyeing, and weaving.

The Hand Loom. — The centuries which have passed since such primitive methods were in vogue have brought many varied suggestions for increasing the efficiency of the loom. Finally the European hand loom (Fig. 34) was developed, on which the modern power loom (Fig. 47) is based. Continuous cloth was made, instead of the rug lengths of an earlier period. Our colonial loom was like the European hand loom, and the weaving was at first done in the homes. It is estimated that there were in this country one hundred twenty-five or more years ago about three and a half million spinning wheels, and a quarter of a million hand looms. When the inventions leading to power spinning and weaving made it more profitable to do the work in factories, a number of them were started in the East, and also

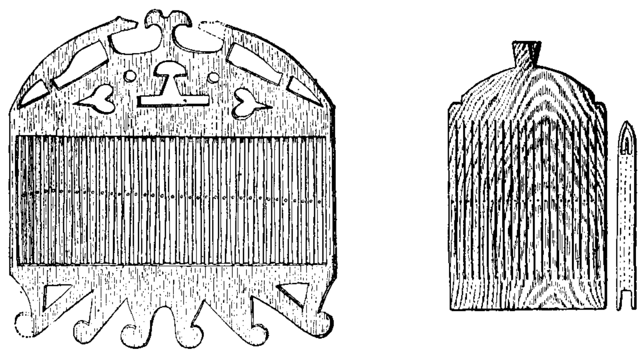

FIG. 35.—PRIMITIVE HEDDLES.

From Watson's *Textiles and Clothing*, by courtesy of The American School of Home Economics.

a few fulling mills were opened. Thus began our textile industry of to-day. The hand loom was used until about 1850.

The Parts of the Hand Loom (Fig. 34) were as follows: (1) *For the management of the warp:* The framework, *C*, usually of wood, and clumsily made, contained a warp beam, *A*, on which the yarn was wound, and a web, cloth, goods, or merchandise beam, *B*, for the finished cloth. These two beams were held in slots at each end of the framework; the warp, *W*, was stretched between them, passing through the harness, *H*, and the reed on the way. Weights on the beams or rollers kept the warp stretched. When the weaving was going on, and the weaver desired to wind up the woven cloth, and at the same time to draw out some of the warp, she could do so without leaving her seat by taking hold of a lever, which on being raised released a paul from a ratchet wheel, and loosened the warp beam. When she had drawn off sufficient warp, and had wound up the cloth, she could fasten the paul on the ratchet, thus holding the warp tight. The earliest looms did not have this device. Inserted through the warp threads back of the harness were two smooth sticks called shed sticks, *D*, which kept the crossing of the warp intact. If a warp thread broke, it could be easily traced by

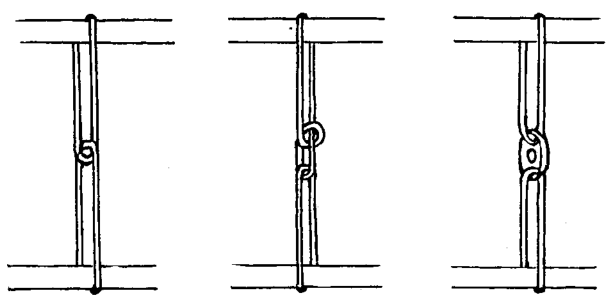

FIG. 36. — HEALDS.

means of these sticks. They were the earliest form of heddle, but are still in use as shed sticks on account of their value. (2) *Shedding:* The harness of the hand loom resembled somewhat a collection of heddles of the Zuni principle (Fig. 35). A series of healds or heddles were made of cord, and suspended on two laths or sticks. The cords were tied in various ways (Fig. 36), but in such a manner that there was an opening in their centers called the mail eye, through which warp threads could pass and be raised or depressed when a particular heald shaft was in use. Threads not needed passed between some heddles to be threaded through others. When a number of healds were on one lathe, it was called a shaft, sheaf or leaf of healds (Fig. 37). The office of each heald shaft was to affect certain threads by drawing them up to form a shed when the pattern required it. The method of threading these shafts, the number to be used and their succession, was indicated by the design and its draft. (See Chap. IV.) For plain weaving two or more shafts were in use. When the yarn was coarse two were sufficient, but when it was fine, four shafts or even eight prevented the friction of the threads. For complex weaving three or more shafts were used. The method of threading the healds and fastening the shafts to the treadles

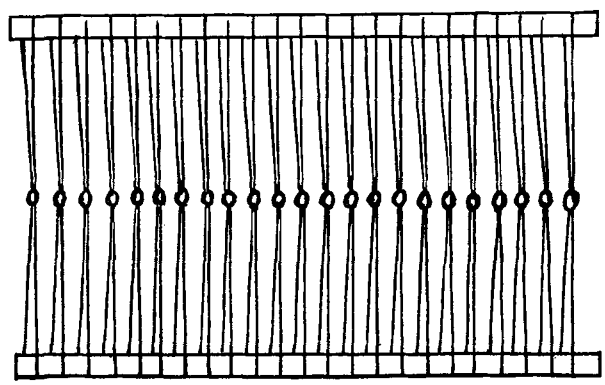

FIG. 37.—HEALD SHAFT.

T controlled the warp threads, which could be drawn down as needed to make the shed (Fig. 38). These shafts were suspended from the framework over a roller, or tied by jacks which worked on a pulley, and therefore could be moved up and down. The shed was made by drawing down the various shafts as needed. (3) *Picking:* This was accomplished by means of a shuttle which held a bobbin or quill with the filling thread. It was boatlike in shape, and had an eye in one end through which the thread from the bobbin came. As part of the warp was depressed the shuttle was thrown through by one hand and caught by the other. A new shed was made and the shuttle returned. A selvage was formed around the last warp thread on either side. Kay's patent of the picking stick and the fly shuttle, and his son's patent of the drop box, put a quicker means of working into the hands of the weavers. (4) *Battening:* The lathe, or sley, *E*, was set into a framework suspended from above or fastened below. It could be easily drawn forward by the hand, and pressed against the finished cloth, making it solid and even. In order to drive home every thread, a reed was set in the lathe. Reeds were made of a series of wires of a varying degree of fineness, according to the coarseness or the distance apart of the warp threads. One or two warp

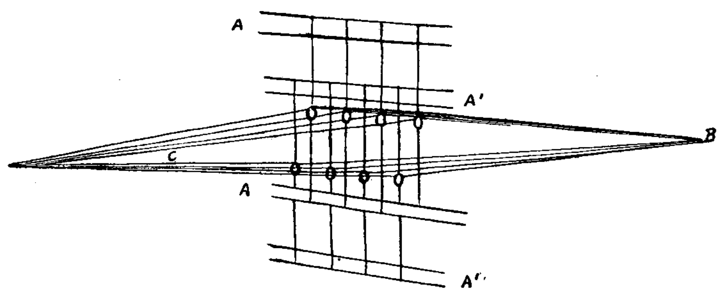

FIG. 38. — DETAIL OF HARNESS, SHOWING ONE HEALD SHAFT RAISED, THUS FORMING SHED.

A, *A'*, Heald shaft. *B*, Warp threads. *C*, Shed.

threads were passed through each dent or division of the reed. The width of the threads as they lay in the reed was the width of the finished cloth. The lathe with its reed was the development of the hand-shaped comb or the sword used in early times. A temple or tenterhook (Fig. 39) held the cloth the desired width and kept the weaver from drawing the threads inward as she worked.

The Working of the Loom. — If a plain design is to be woven, every other warp thread must be up while the alternate threads are down. Consequently if two shafts are used there will be one treadle tied to each; but if four or eight shafts are used for plain weaving, two or four will be fastened to one treadle and two or four to the other. The usual way in hand loom weaving with four shafts is to fasten the first and third shaft to one treadle, and the second and fourth to the other. It is more common in power weaving to have the first and second shaft act together, and the third and fourth. The healds are threaded in such a way that the odd numbers, such as 1, 3, 5, 7, 9, etc., will be in the first and third shafts, and the even numbers in the second and fourth. The drawing-in is from the back of the loom and from the left to the right. The weaver depresses one treadle, with the threads attached to it, leaving the alternate ones up.

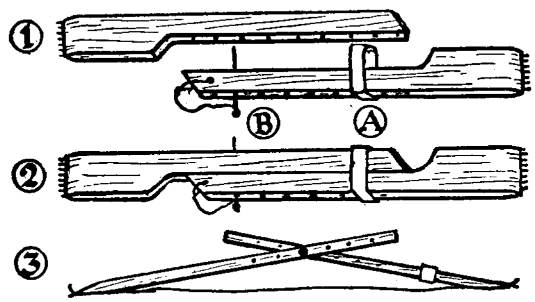

FIG. 39.—TEMPLE OR TENTERHOOK.
From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

She throws the shuttle containing the filling which passes out from the eye, leaving a thread behind in the shed (Fig. 40). She draws forward the swinging lathe or batten with its reed, through the dents of which are the warp threads, and drives the filling home. She then pushes back the lathe, and is now ready for the alternate shed. She removes her foot from the first treadle, and depresses the other, proceeding as before. If a thread breaks, as frequently happens, she stops to find it. The shed sticks are of use to her in tracing it, for it frequently breaks and springs back all the way to the warp beam. She must, therefore, after she has found her thread, tie a new piece of yarn to it with the weaver's knot, bring it under and over the shed sticks, through the correct eye of the heald, and up to the cloth, where she holds it in place until she has woven

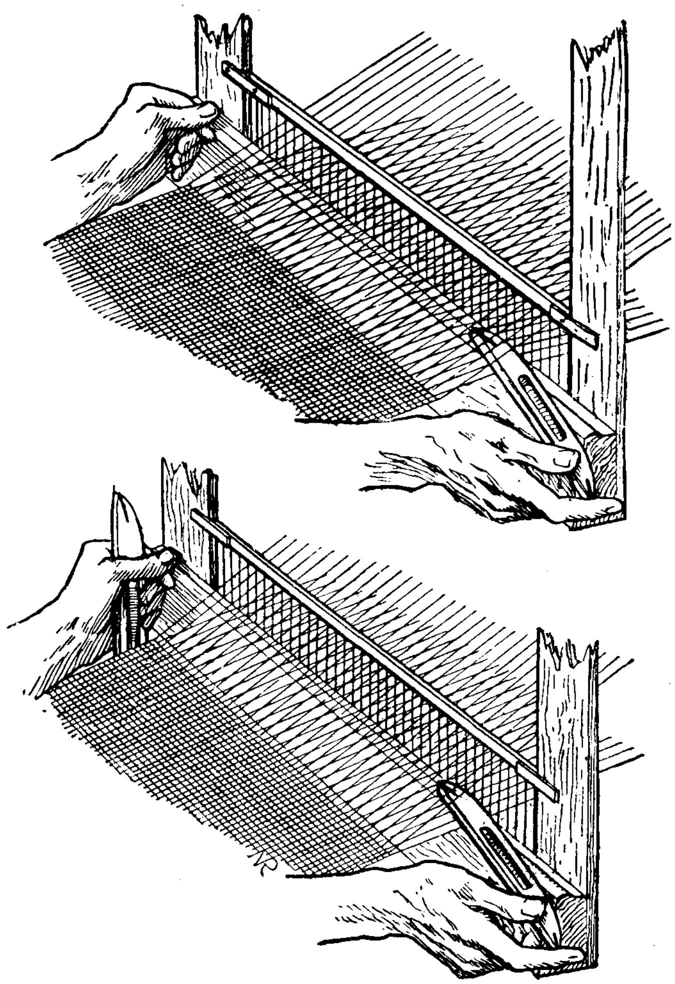

Fig. 40. — Throwing the Shuttle through the Shed.
From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

a few lines. After it is well woven in, the end can be cut off. If the filling gives out, or a new color is to be used, she opens the shed which contains the end of the last thread, lays the new thread an inch over the old, battens the new into place, and continues weaving as before.

Winding, Reeling, Warping, and Drawing In. — The threading of the hand loom is a tedious process. The procedure is virtually the same in the power loom. A warp is formed of as many threads or ends as are needed in the width of the cloth. Each thread must be the same length and wound smoothly on the warp beam. An important part of successful weaving is the preparation of the warp and the threading of it into the harness, or the drawing in. This was done by hand at first, but power now accomplishes the same result by an elaboration of parts which take the place of the hand. The necessary steps as taken by the hand workers are given in the following outline:

1. The bobbins of spun yarn are taken from the spinning wheel.

2. The yarn is wound from the bobbins on a reel, thus making a skein of definite length. The clock reel (see Fig. 8) is used, as the click indicates the time when the skein should be tied or removed.

3. The skein is put on a swift (see Fig. 8) and the yarn is run off on bobbins.

4. Bobbins to the number required are put on a creel, scarne, or bobbin frame. (See Fig. 9.)

5. The creel with its bobbins is put in front of the warping bars. (See Fig. 44.) The yarn is drawn from the bobbins to make the warp, a lease being kept carefully at one end of the warp.

6. The warp is taken from the bars or from the drum in (1) a chain form; (2) on a niddy noddy (see Fig. 8), or (3) on a stick, the lease always being carefully preserved.

7. The chain is taken to the loom, from which the harness has been removed. A special frame holding the warp beam is sometimes used. Two people are required to do the work. One lets out the chain from the end taken last from the bars or drum, and the other rolls up the warp on the beam as the chain is let out.

8. Cords are put through the lease of sufficient length to stretch the warp to the purposed width of the cloth. Careful watch is kept for broken threads or for threads out of place.

9. The threads must now be attached to the warp beam. They are slipped over a thin, flat stick which is attached to a piece of cloth fastened to the warp beam. Holes are punched at intervals in the cloth, and strings through these holes are tied to the stick. The warp threads or ends are stretched the required width on the stick.

10. The warp threads are distributed evenly on a raddle (Fig. 41) to a couple of inches wider than the cloth will be. The raddle is placed near the warp beam, that the ends of warp may pass through it and wind smoothly on the beam.

11. The warp beam is slowly revolved by one worker and the chain is let out by the other, who stands on the other side of the raddle. The threads

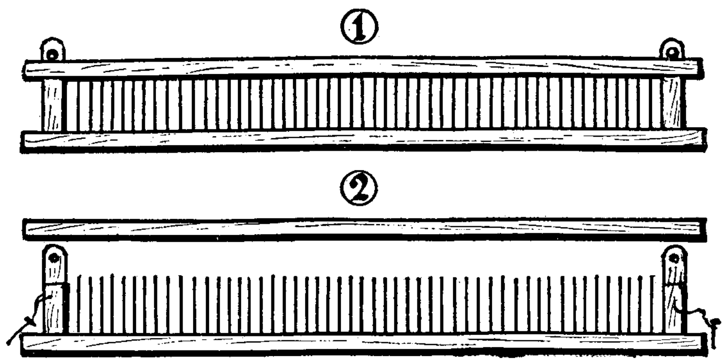

FIG. 41.—RADDLE.

From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

pass through the raddle and the lease and are wound up evenly on the beam until the end of the warp is reached. A coarse brush is often used to lay the threads parallel.

12. Two sticks are placed through the lease in place of the cords. They are tied together at each end to keep the threads from slipping off. The raddle is removed, the threads of the warp are cut through and tied in bunches of ten or twenty on the harness side of the lease. It is extremely important that the threads shall go through the harness in the exact order that they come from the lease.

13. The ends of warp are now threaded carefully through the eyes in the healds of the harness. The order in which this shall be done depends upon the particular pattern required, and is indicated by a draft. (See Design and Draft.)

14. When the threading of the harness is complete, the warp threads are taken one by one through the correct dents in the reed (Fig. 42).

15. The warp threads are passed over the breast beam and fastened evenly to the cloth beam in the same way as on the warp beam.

In general, when a warp comes to an end in a loom the threads are not pulled through the harness, but are left hanging in small groups and are tied together so that they cannot slip through. When that arrangement of harness is needed again, the new warp threads are tied to the old by a flat or weaver's knot, or twisted one by one to each of the former threads. This method saves much time. A good worker can twist in seven thousand new threads in a day. Machinery which does this work as well and more rapidly

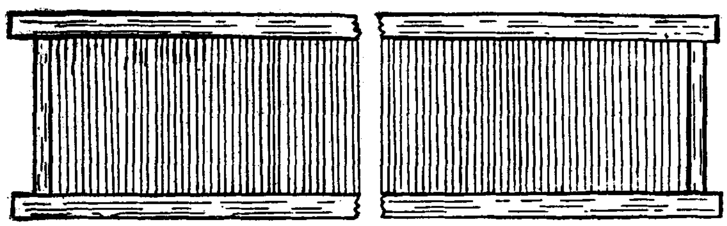

FIG. 42.—REED.

is on the market. It is expensive and not found in the smaller mills. Hand threaders are generally employed. Two workers are usually found sitting on either side of the harness. One pushes the warp thread through the mail eye with a little metal device, and the other receives it. Single warp threads are sized before weaving and after they are on the beam, to give them strength to bear the strain. Filling threads are not sized. For numerous details of warping and drawing in, see *Hand-loom Weaving*, by Luther Hooper.

Several processes mentioned in the above outline are given in greater detail below.

The creel (see Fig. 9) is an upright frame with a number of wire rods across it on which bobbins filled with yarn may be slipped. Threads are drawn from all the bobbins at once. The creels used by hand workers are of various sizes, carrying from ten to eighty bobbins. Those used for power warping frequently hold many hundreds. In hand warping the creel filled with its bobbins is placed beside the warping bars or

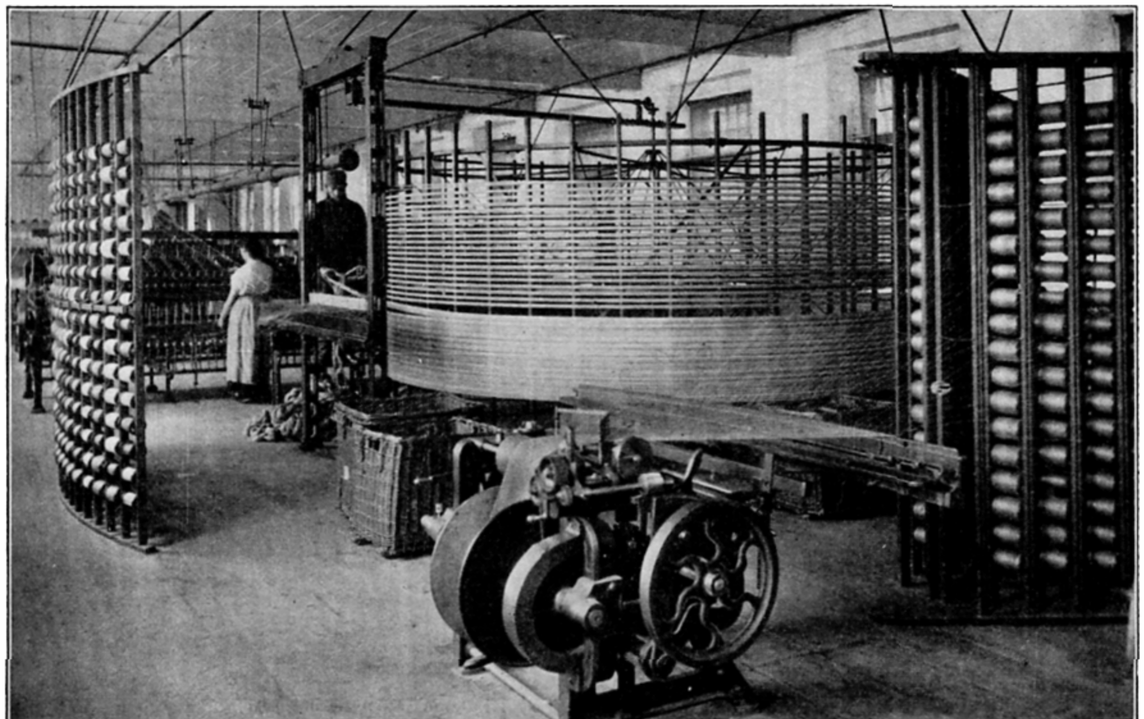

FIG. 43.—HAND AND SECTIONAL WARPING. THE ATTENDANT IS REMOVING A WARP IN CHAIN FORM FROM THE DRUM.

Courtesy of The York Street Flax Spinning Co., Belfast.

drum, that the threads may be drawn from it for the warp. (See big reel in Fig. 43.)

Warping. — The purpose of warping is to lay in parallel order the required number of threads for the width of the cloth. These threads must be the length of the finished cloth. The method used is to draw a small number of threads to the required length and repeat until the full number for the width is secured. If a drum three yards in circumference is used and ten threads from the creel are carried ten times around it, the result will be ten threads thirty yards long. By reversing the movement of the drum and carrying other ten threads back, there will be twenty threads thirty yards long. The same work may be accomplished by a series of pegs, called warping bars (Fig. 44), set at a distance of three yards apart, on which the yarn is carried back and forth.

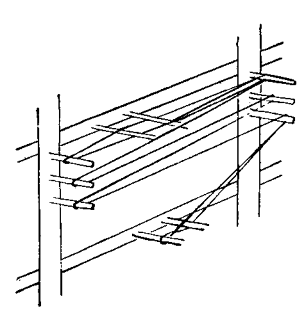

FIG. 44. — WARPING BARS.

Making the lease is an important part of warping, for thereby the threads can be kept in perfect order, or if they become tangled can be set right again. Three pegs are placed on the warping bars or on the drum for the purpose. The threads are drawn from the creel, the ends knotted together and placed over the first peg on the drum, the two remaining pegs being used for the lease. The warper begins by grasping the threads coming from the lowest row in the creel in the palm of her hand, twists her hand as she takes the second row, so that these threads pass over its back, and continues this alternation through the succeeding rows. She now has the lease in her hand and places it on the pegs, noting the order of placing. She revolves the drum, letting the threads from the creel lie on its surface, until she has drawn out the length of the warp. At this point there are two pegs, around which the threads are wound under and over, but not in a lease, before bringing them back over the same track. She ties the bunch of threads together that she may later count them more rapidly. By reversing the drum she brings the threads back to the lease pegs. She must now make the lease again, remembering that she is reversing the manner of making it, but preserving the first plan. If the manner of placing has been such that the threads on the palm are on the

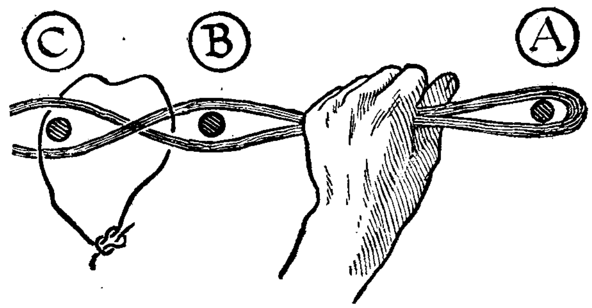

FIG. 45.—TAKING OFF THE WARP.
From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

second peg and those on the back of the hand on the third, on the return the reverse order brings the threads on the back to the third peg and those on the palm to the second. When the warp is complete and ready for removal two cords are inserted in the lease to keep the alternation perfect, and a cord is tied over all the groups of threads at the end. The first peg, to which the threads from the creel were tied, is removed, which loosens the warp, and it is taken off by looping it into a chain or taking it around a stick or niddy noddy (Fig. 45).

Power warping accomplishes the same object as hand warping. Many methods have been invented to meet peculiarities of the fibers. Filmy silk threads require different handling from cotton or wool. The yarn is in general prepared for warping on a spooling frame, and the bobbins or spools are placed in the creel. The threads are all drawn through a coarse reed. A lease is made automatically, a measurer indicates the length of threads passed through, a stop motion throws off the power if a thread breaks, and a distributer winds the threads evenly on the beam. Large drums or reels for winding the entire warp at one time, and also sectional warpers are used. (See Fig. 43.) The latter forms the warp in small divisions to be later united on one beam. Creels are V-shaped and also semi-circular.

Taking Off the Finished Cloth. — The warp threads are cut a few at a time far enough from the finished cloth to prevent raveling, and from the harness so that they will not pull through. They are then tied with a flat knot in small bunches, to keep them from slipping through the mail eyes of the harness. The paul is released from the ratchet and the cloth beam is taken out and the cloth unrolled.

Tapestry Looms. — The modern tapestry looms are found in horizontal or vertical form, the latter looking much like the vertical looms of antiquity. The warp is stretched tightly in the frame, and the pattern is put in by the fingers. The filling is inserted as a plain weave, but the use of color forms the pattern. Many colors are often used for the filling, and are usually put in by a sort of needle or bobbin. Two heald shafts are generally used, so that the alternate threads can be raised together and simplify the weaving, not only when the filling is to be thrown all the way across the warp, but also when only a small section is needed. The vertical loom was quite usual in Europe until about 1400, when a horizontal loom took its place. France developed tapestry weaving in the time of Francis I., especially in the city of Arras, the weaving being called Arras work. Raphael and his students were designers for these tapestries. The Flemish tapestry weavers were considered the finest. Ghent formerly had seven streets devoted to this class of weaving. Although the industry has declined, tapestries are still woven. Some of the noted modern studios are the Gobelin atelier in Paris; the weaving sheds at Merton Abbey in England, where William Morris revived tapestry weaving; and the studios of Albert Herter in America, where French Aubusson weavers are employed, the work being done on horizontal looms.

CHAPTER IV

POWER WEAVING

The Transition to Power Weaving. — During the early Middle Ages an increased demand arose in Europe for rich and elaborate materials. It was difficult to weave these on the plain hand loom. The Crusaders are given the credit of introducing the Draw Loom into Europe from Damascus, the term damask, used for elaborately designed linen, being taken from this city. The hand loom was naturally limited in the number of heald shafts and treadles which one worker could control. The draw loom allowed a wide scope in patterns. The shed was controlled by a series of cords attached to the heald shafts, which were pulled down in succession by an attendant called the "draw boy." The weaver gave his attention to the weaving. Later an automatic attachment providing for mechanical shedding was invented, which took the place of the boy. A similar loom without the automatic attachment is still used in the East.

In 1678 a loom was invented by M. de Genres of France, which embodied many modern principles, but little was heard of it. In 1745 another Frenchman, M. Vaucanson, brought forward his loom, which had the principle of shedding later used by Jacquard. It also had an embryo friction roller and a take-up motion, which are now found on the modern power loom. The invention of automatic spinning in England gave an impetus to weaving in that country. In 1733 John Kay invented the fly shuttle (Fig. 46) which increased the power of the weaver many times. He placed a shuttle race on the lathe, with a box at each end to receive the shuttle which the hands of the weaver had caught heretofore. Each shuttle box had a picker stick or driver connected with it, which when moved threw the shuttle across the race and through the shed. The motive power for the picker stick was a cord extending from one driver in a shuttle box to the other, and a peg in the center of the cord was held by the weaver. If he wished the shuttle to fly from either side, he drew the handle sharply to the opposite side, which caused the driver to give a sharp blow to the shuttle.

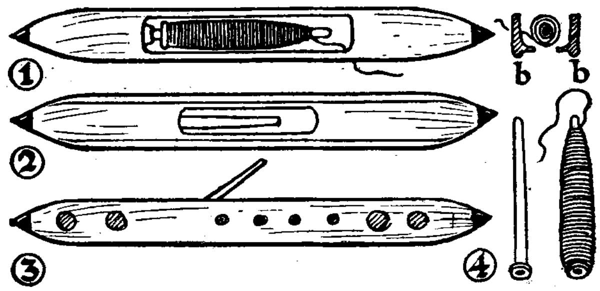

FIG. 46. — FLY SHUTTLE.

From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

The hand looms before Kay made twenty picks per minute, but the fly shuttle increased this to forty picks, and further improvements made possible sixty picks per minute. The early power loom brought the record up to a hundred picks per minute with one man in attendance. To-day one man can attend to from four to six looms, which according to the kind of materials woven will make generally from two hundred to two hundred sixty picks per minute, and have even made four hundred. On plain goods at the present time, one weaver has watched as many as two dozen looms.

In the middle of the eighteenth century it was still necessary to stop the hand loom every time a new color was needed in the filling, in order to place a bobbin or quill with this color in the shuttle. This difficulty was met in 1760 by Robert Kay, the son of John Kay, by his drop box. Several shuttle boxes were placed at one or at both ends of the lathe in place of one at each end. The shuttles held bobbins of different colors, and the boxes fell into place automatically. These two inventions of the Kays were of great importance in the history of weaving, and helped to bring on the Industrial Revolution. They made more weaving possible, but the spinning wheels of the day could not provide enough warp. The inventions of Hargreaves, Arkwright, and Crompton, however, made increasing quantities of yarn possible, and more effective weaving was soon needed. In 1775 a power loom was invented which had much merit, but unfortunately was not pushed. It was 1785 before Dr. Cartwright, of England, a clergyman of the Established Church, who had mechanical genius, brought out a heavy automatic loom. It was later improved and became the basis for the power looms of to-day. It required mechanical power to move it, the hand not being strong enough.

The Power Loom (Fig. 47). — The hand looms passed away slowly before the power looms. In 1830 Roberts invented his power loom which had a majority of the parts of the modern loom, and therefore required little attention. The hand weaver spent much of his time letting out the warp, winding up the cloth, moving the temple or tenterhook, changing bobbins in the shuttle, and mending broken threads. The modern power loom is a time saver, for everything is automatic. The harness, the pacing, or the let-off and take-up motions of warp and cloth, the self-acting temple, the fly shuttles and drop boxes move smoothly without attention. A detector in connection acts when the bobbin in a shuttle is empty, and causes the magazine to pass a new bobbin to the waiting shuttle, which can then finish its path. The empty bobbin falls into a receptacle below. A loose reed invented in 1841 (a fast reed had been used previously and is still in use) is so placed on a movable retaining board on the lathe that it can be pushed out when there is sufficient warp obstruction, thus stopping the loom and preventing further damage. When a shuttle leaves its race and plunges into the warp, technically called a smash, much harm will be done, if the loom continues running. The electrical

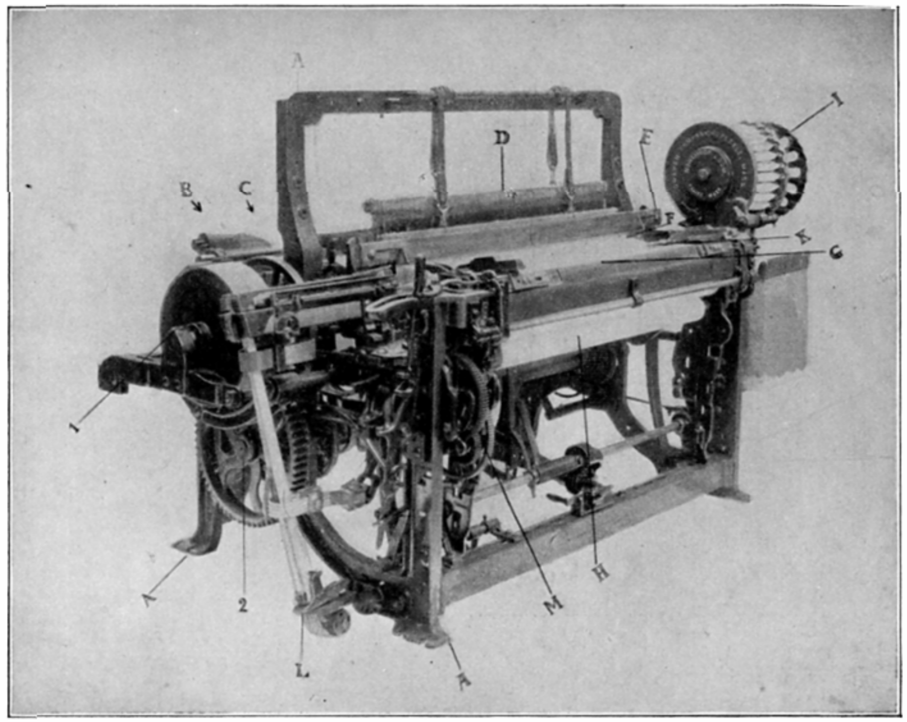

FIG. 47. — POWER LOOM.

Courtesy of The Draper Company.

" stop-motion " prevents this. It consists of wires which drop between the warp threads. If a thread breaks, the wire falls and completes an electric circuit which stops the loom. The filling stop is a weft fork which drops as the thread breaks.

It is easier to understand the power loom of to-day, if the principles underlying weaving and the simple parts of the regular hand loom of colonial days are understood. The power loom differs only in the multiplicity of parts necessary to take the place of the human hand.

Parts of the Plain Power Loom. — (1) *The Framework*, *A*, usually of cast iron, which holds the working parts. (2) *The Warp and its Manipulation.* The warp (ends) is wound on a beam, *B*, placed at the back of the loom. The figure does not show the beam; the letter *B* indicates that it is below. It passes over the whip roll, *C*, not shown in the figure, through lease rods or shed sticks to the harness, *D*, through the reed, *F*, which is in the lathe or sley, *E*, and over a breast beam, *G* (the place is indicated), to the cloth or goods beam, *H*. A temple, *K*, holds the width of the cloth near the last threads woven. An automatic letting out and taking up motion, *M*, gradually winds up the cloth on its beam as it is woven, and proportionately lets out the warp. The action is regulated through a cogged wheel set to the number of picks per inch in the cloth. In case of breakage the warp stop motion stops the loom. (3) *The Shedding.* This is effected by the motion of the harness, *D*, which is composed of as many shafts or leaves of healds as the pattern demands. (For Drawing-in, see below.) If a drawer-in has made an error and placed a wrong thread through any mail eye of the heald, it is sometimes rectified by removing the thread from the eye, taking a new bobbin, threading the heald with a thread from it, and carrying this thread through to the cloth beam. The bobbin is put on a spindle at the back of the loom to unwind with the warp threads. There are two methods of shedding, the closed and the open, based on different ways of separating the warp threads. (4) *The Picking.* By means of the picker stick, *L*, on each side, the shuttles, carrying filling bobbins, are thrown across the race on the lathe, *E*, when a shed is made, entering the shuttle boxes first on one side and then on the other. A stop motion is connected in case the filling breaks. Single or drop boxes or a magazine, *I*, are used to hold the shuttles. (5) *The Battening*. This is effected by the reed, *F*, combined with the weight of the lathe, *E*. The reed may be fast or loose in the lathe. (6) *The Temple*, *K*, holds the cloth firmly at either selvage. As threads are often strained by the temple, it is customary to have a close weaving near the selvage, or twisted or stronger threads are used in the warp at each side. Mistakes made in weaving because of broken warp threads sometimes do not show until the finishing, and are then hard to repair; therefore in some kinds of cloth weavers will raise the shafts of the harness several times a day to be sure each mail eye is filled with its thread of warp. Warp threads are frequently sized beforehand to make them smooth and strong for the strain of weaving. The jar on the warp is often so great in stopping the loom that a spring has been put on the framework to lessen the shock.

The Driving Parts of the Plain Loom. — Methods of actuating the loom differ somewhat in the various makes, but the following is representative of the direct loom control by the main shaft: The main or crank shaft, 1, extends a little beyond the framework, *A*. It is driven by a pulley, and is connected by wheels with the lower shaft; consequently the motion of the former is communicated to the latter or is reciprocal. The main shaft is cranked, and has connecting rods which give motion to the lathe, *E*, which oscillates on sley swords. The number of movements of the lathe is governed by a wheel which is set for the number of picks per inch in the cloth. The taking-up or pacing motion of the warp and cloth beams is connected with the motion of the lathe, and causes the cloth roller to move forward with each oscillation. The taking-up roller is a friction roller which moving against the cloth beam winds up the cloth. The other parts of the loom are moved by the lower or tappet shaft, 2. The transfer of power from this shaft to the other working parts is by a tappet wheel or by cams. By means of this lower shaft, the harness, *D*, which forms the shed, is depressed as needed by a tappet or by cams acting on the treadles. The picking motion is also controlled from this lower shaft through the arms of rocker shafts hitting the picking sticks alternately and thus throwing the shuttle back and forth through the warp each time the shed is made.

The loom is sometimes controlled through the lower shaft or by indirect motion. Many consider this gives a more uniform action of the parts. Whatever method is pursued, the important thing is the careful timing of each motion, so that one will succeed another without interruption, injury to the cloth, or too constant attention of the weaver or the loom fixer.

Looms vary somewhat according to the materials woven upon them. The terms "ribbon looms," "gingham looms," "worsted looms," "plush looms," "double cloth looms," and "carpet looms" are illustrations of adaptations to needs. The fineness of cloth is expressed by the number of picks and ends per inch with any count of yarn; thus in cotton 32 ends and 26 picks is coarse and 80 picks by 92 ends is very fine.

The modern power loom has become an almost perfect machine, the modern weave room a bewildering, throbbing mass of machinery. (See Fig. 96.) The inventions of the present are toward greater rapidity and toward the correction of small defects. Illustrations of this are the warp tying machines, invented to take the place of the "drawer-in"; elimination of oil stains; devices to prevent slack threads in the warp or bunches in the cloth from almost spent filling; or imperfect action in the numerous parts, such as skips and unevenness in the weaving. A simple power loom costs from $50 upward.

The Jacquard Loom (Fig. 48). — Harness looms are limited in pattern, but the Jacquard loom allows four hundred or more changes — practically an unlimited variety. The cost of working

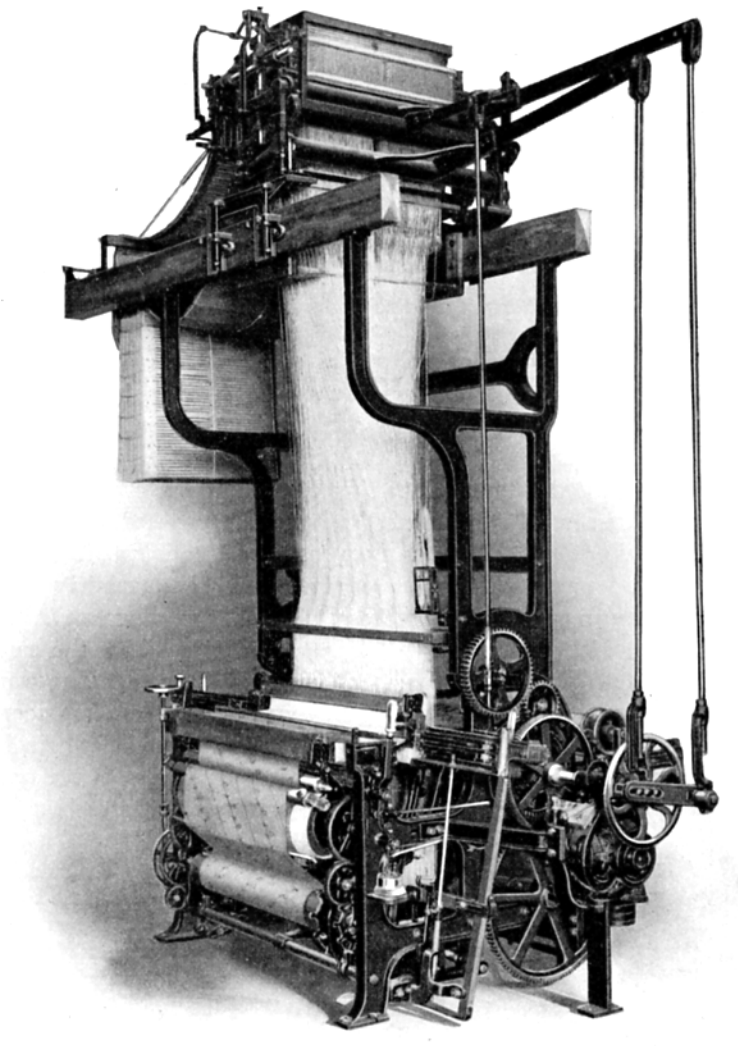

Fig. 48. — Jacquard Loom.

Courtesy of Crompton and Knowles Loom Works.

on the Jacquard is greater than on the plain loom. A twill containing sixteen changes (16-end) can be made on either the Jacquard or the harness loom, but the expense would be less on the latter.

The Jacquard was invented by Joseph Marie Jacquard, a straw hat manufacturer of Lyons, France, in response to a demand for a method of weaving more elaborate designs in silk and linen materials. His ideas were undoubtedly drawn from the Vaucanson model. The loom which at present is known by the name of Jacquard has many improvements over the original. The invention consists of a new method of shedding (Fig. 49), influenced from above the harness, whereas the harness loom is by treadles worked from below. It may be said in a general way that the principle of making the shed in the Jacquard loom is the raising of the harness cords (healds), *A*, by means of wire hooks, *B*, to which each cord is attached at its upper end. Each harness cord has a mail eye, *C*, through which a warp thread passes; consequently if the cord is drawn up, the warp thread rises also. Weights or lingoes, *D*, are attached to each cord at its lower end, which draw the cords back into place after the hooks have raised them. The warp threads are stretched between beams, as in the plain loom. In the Jacquard harness each warp thread is influenced singly, including the repeats of any one. In the simple loom the warp threads are controlled in the groups on any one shaft.

There are single and double lift Jacquard machines. The principal parts of the single lift Jacquard harness are the harness cords, *A*, the hooks, *B*, the mail eyes, *C*, the lingoes, *D*, and the beams (these have been mentioned already); the griffe or hook lifter, *E*, consisting of a series of blades, knives, or bars, which lift the sheds as do the tappets or cams of the plain loom; the needles, *F*, which work horizontally, and have one end bent back to come in contact with the spring in the spring box, *G*, and an eye in the center, *H* (the double lift machine has two eyes in the needle), to allow the hooks to pass through. The duty of the needle and cylinder, *I*, is to press forward against cards, which indicate the pattern and are against the batten. The needles govern the hooks, *B*, which pass through their eyes. The

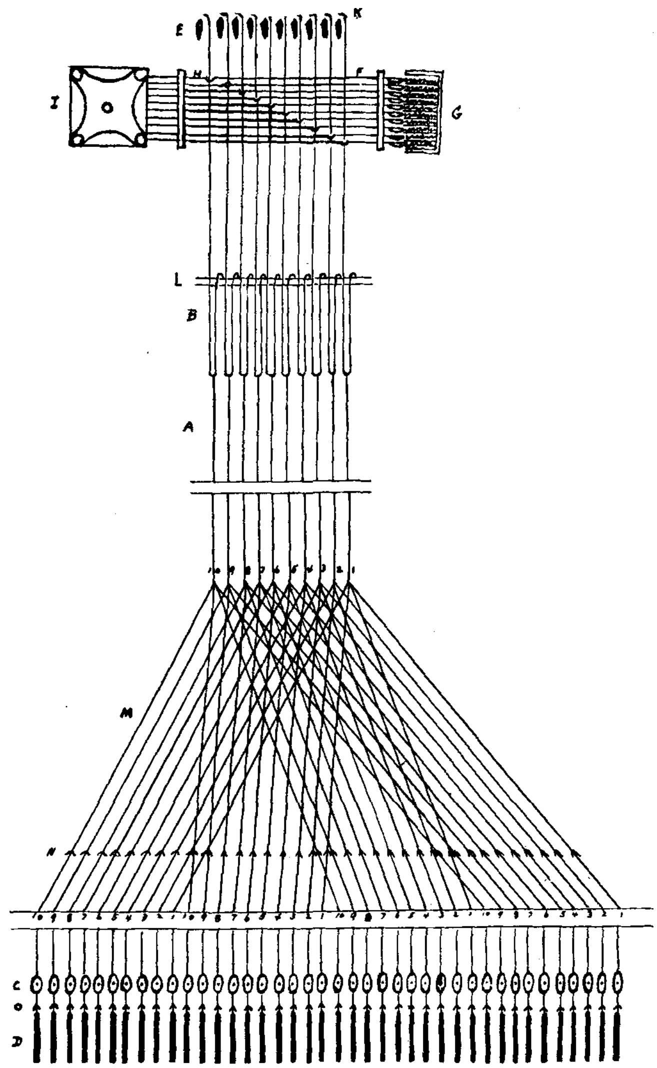

FIG. 49.—DETAIL OF JACQUARD LOOM.

A, Neck cords. *B*, Hooks. *C*, Mail eye. *D*, Weights or lingoes. *E*, Griffe or hook lifter. *F*, Needles. *G*, Spring box. *H*, Needle eye. *I*, Cylinder. *K*, Catch of needles. *L*, Hook rest. *M*, Additional harness cords. *N*, Couplings joining upper and lower parts of harness. *O*, Knots holding heald lingoes to cords. *P*, Comber board.

hooks work vertically and are made with a catch, *K*, at one end, which goes over the griffe but can be easily detached. They rise automatically with the griffe unless the needles are pushed back by the cards, which will throw the hooks from the griffe, thus lowering the warp threads and making a shed.

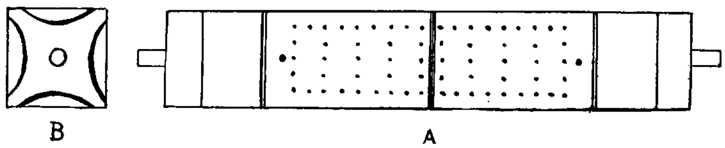

FIG. 50.—CYLINDER OF JACQUARD LOOM.

A, Cylinder. *B*, Cross section with cards.

The cylinder (Fig. 50) has four sides, and cards pass over it, coming in place alternately and indicating the pattern by pressing back those needles which are not required to raise the shed. The cylinder makes one quarter of a revolution with each pick of the pattern, thus placing one of its four sides in contact with the needles. The complete design is on the cards (Fig. 51), and each one represents one pick of the pattern. The cards are laced or tied together in perfect order at each end and in the center (Fig. 52). When

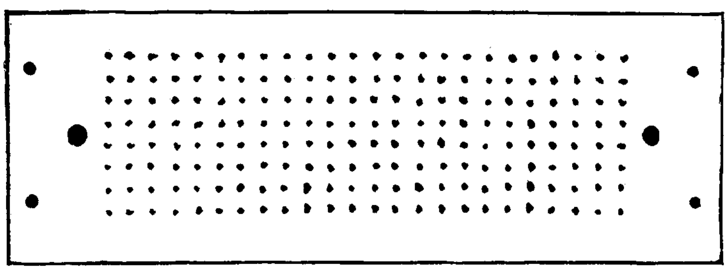

FIG. 51.—CARD OF JACQUARD LOOM.

the pattern is completed the succession of cards begins again. The cards fall in place at the right moment against the cylinder. If there are holes in the card, they come directly opposite those in the cylinder. All the needles advance automatically, and some of them pass through the holes in the card. Those that do not pass into holes are thrown back and the hooks attached to them are thrown from the griffe, thus lowering the shed.

Figure 49 shows only a part of the threads of the harness. For the complete loom see figure 48. The neck cords, *A*, are attached to additional harness cords, *M*, which give repeats to the pattern if any one of the neck cords are raised. At *N* are a series of knots or couplings, which connect the upper and lower portions of the harness, and at *O* are the knots which hold the heald lingoes to the cords. The comber board, *P*, keeps the harness cords from tangling, for each cord is passed through a hole in the board up to the neck cords. The number of cords in the comber is regulated by the threads per inch in the warp. The comber is divided into as many sections as there are hooks in the machine. An iron frame incloses the working part of the Jacquard loom. The power is applied as in the plain loom.

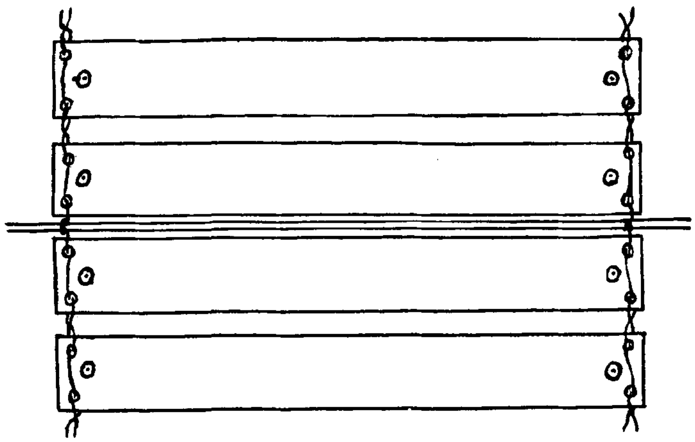

FIG. 52. — LACING OF CARDS (Jacquard Loom).

There are many varieties of Jacquard looms, from the small one hundred needle to the two thousand needle machine. While they vary in some particulars, there is a general standard. The double lift machine generally has eight hundred hooks, two to each thread, and also two griffes. Two patterns can be made at one time upon it, one for background and one for figure, as in damask table linen. The expense of the Jacquard lies in the making of the cards, the setting up of the harness, and the slow motion of the loom. For setting up an elaborate design requiring four thousand cards and four hundred needles, the cost would be about $120. The arrangement of the harness for such a design would take a man about five weeks. Exception-ally elaborate designs will have as many as twenty thousand cards at a cost of $600, and the setting up of the harness would be the equivalent in time of a year's labor of one man. Lace curtains are woven on special Jacquard looms in which there are three lines of threads, a warp beam holding those which run straight, bobbins holding the zigzag threads, and the pattern is made by threads coming from spools. In the ordinary Nottingham curtain as many as seventy-two hundred threads are often in the harness of the Jacquard. The lace curtain looms are very wide. Carpets, such as Brussels, Wilton, and Axminster, are woven on specially adapted Jacquard looms.

The making of the cards requires special machines, one for cutting and another for duplicating. Each design is made first on squared paper in the usual way. The cards are first printed with a series of dots upon them. Each card is to represent one pick of a pattern, therefore holes are punched through the dots when the pattern appears on the surface. The worker has the design before him and reads a line across, punching the cards as he reads. His machine is similar to the typewriter. The cards are carefully numbered as they are punched, and are later laced together and hung over the cylinder of the Jacquard.

The expense in Jacquard weaving led to further inventions by which the effect could be attained without the cards and elaborate harness. An English invention, the *dobby* attachment, which is placed on the harness loom, is an illustration (Fig. 53. Dobby in upper left-hand corner). The result of its work is similar to the Jacquard, but the shedding is effected by a chain of narrow strips of wood (lags) into which pegs are placed which indicate the pattern and take the place of the cards. Each lag represents a pick of the pattern. On reading the design for the pattern a peg is inserted when the pattern is on the surface. In the loom the work of the pegs is to raise the harness. They travel around the cylinder and come in contact with the levers which lift connected hooks, and the latter raise the shafts attached to the hooks and make the shed. A second chain controls the shuttle. Multiplier chains duplicate the pattern and save time which would otherwise be taken in preparing the lags. The modern dobby offers almost unlimited possibilities.

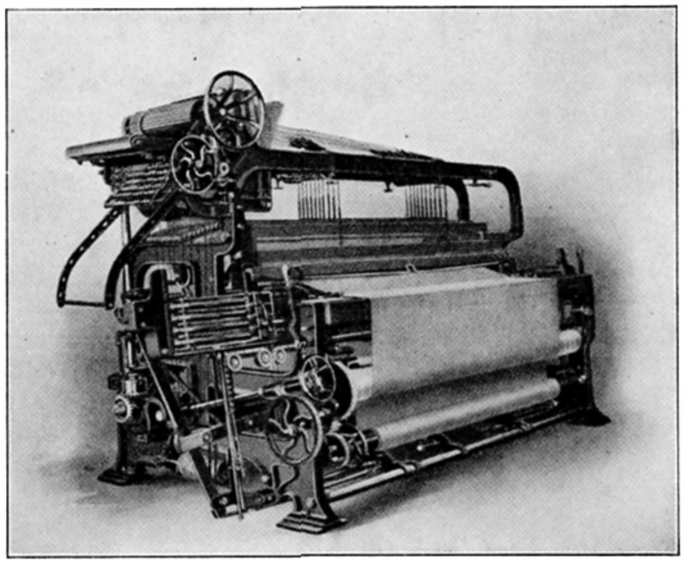

FIG. 53.—LOOM WITH DROP BOX AND DOBBY ATTACHMENT.
Courtesy of Crompton and Knowles Loom Works.

Another method of weaving intricate patterns without the use of the Jacquard harness is by the *head motion* attached to the harness loom (Fig. 54, showing detail). This is an American invention and is used extensively in the United States. The heald shafts in the loom are elevated or depressed by pulleys, but the series of mechanical devices which actuate the pulleys is quite different from the English dobby system. It is claimed that the head motion is simpler and more steady than the dobby. The pattern chain consists of high and low links, which control the elevation and depression of the shafts.

The chain is made of a series of rods on which bowls or small

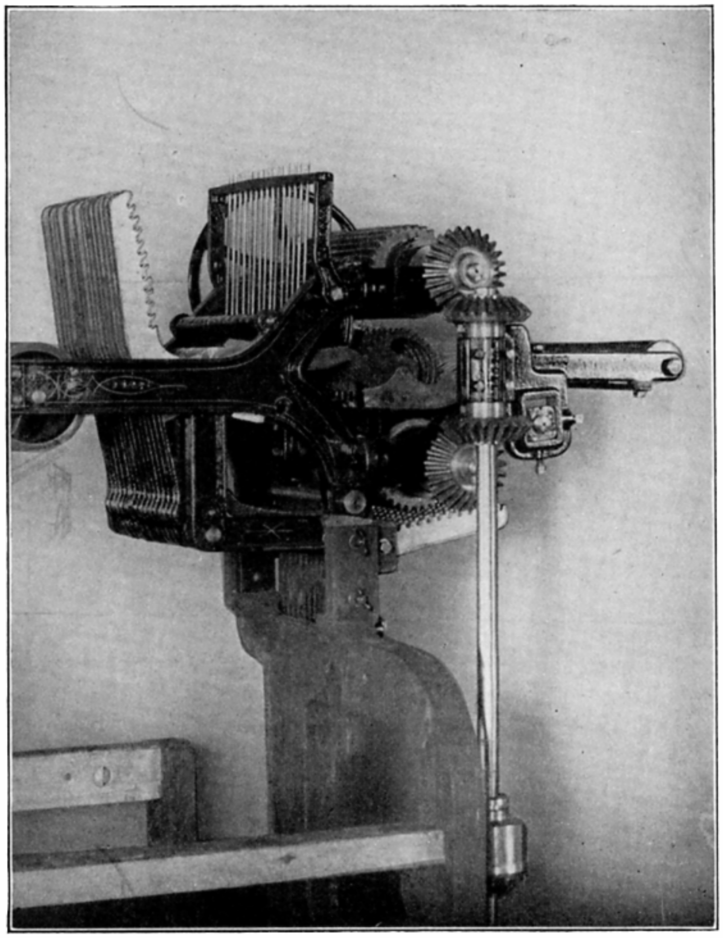

FIG. 54.—HEAD MOTION.
Courtesy of Crompton and Knowles Loom Works.

pulleys and lifters or risers and tubes called sinkers are arranged according to the requirements of the design. The chain lifts the shafts by means of the bowls or risers which come in contact with vibrators, and they again with the lifting cylinder connected with the heald shafts. A second chain is used to control the shuttle. A reversing motion is connected which is of great value when mistakes in weaving have been made.

Patterns may be woven on the surface of cloth to resemble hand embroidery, with an attachment to the regular loom called the *lappet*. It affects the shedding, and is used extensively for decorative cotton goods. The embroidery may be continuous or intermittent. The floating threads left on the wrong side of the cloth by the lappet frame are shorn off later by a finishing machine especially adapted to the purpose.

Swivel Weaving is somewhat similar to the lappet. It is used extensively in weaving silk ribbons and broad silk materials. The swivel attachment affects the picking motion and produces small continuous or intermittent figures without continuing the thread from one side of the material to the other. It thus prevents the waste of valuable silk by using it only when necessary. The cards of the Jacquard machine can control the swivel patterns. Swivel attachments are expensive and the action slow. The lappet frame is more economical. There are other varieties of embroidery attachments.

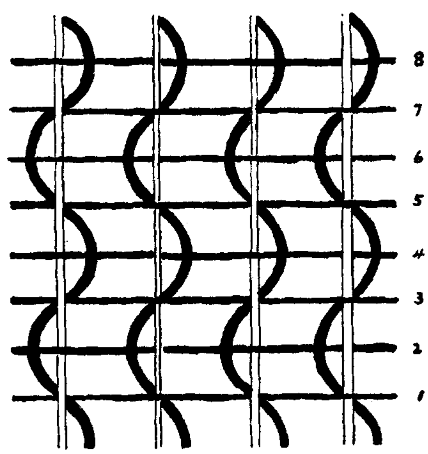

FIG. 55.—GAUZE WEAVE.

Leno or Gauze Weaving departs from the usual straight lines of warp, for in it adjacent warp threads twist about each other in various ways, letting the filling pass through, thus holding the cloth together and keeping the threads from untwining (Fig. 55). The work is a sort of wattling and may be simple or elaborate. Leno weaving (Fig. 56) depends upon the manner of threading the harness. There is a standard heald and a doup heald. The latter can be drawn first to one side and then to the other of the standard heald, and the gauze can thus be made as desired. When closely woven, Leno weaving is enduring, but much of it is unsatisfactory. Marquisette is woven in this way. The same principle is used for making the yarn for chenille curtains.

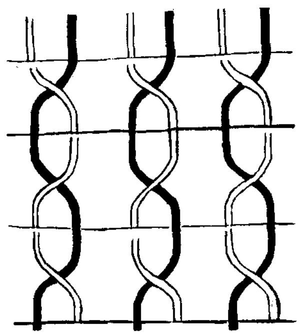

FIG. 56.—LENO WEAVE.

Pile Fabrics. — Terry fabrics used for Turkish toweling and other pile goods are made on looms which at intervals omit a couple of picks of filling and then push the warp together into loops. These are held in place by succeeding filling threads (Fig. 57). In cheap grades, the loop thread is easily pulled out of its place, for few filling threads are inserted between.

Silk and worsted velvets and warp plushes are made in various ways. Good qualities of silk velvet are woven much like Wilton carpet, that is, an extra warp passes over a series of wires having sharp edges, which when withdrawn cut the loops of warp. The cutting of silk velvet is along the width, that is, the warp is cut. Silk-faced velvets often have cotton backing. Cotton velvet is woven differently from silk velvet, the pile being made by the filling, and the cutting is along its length. Some plushes are

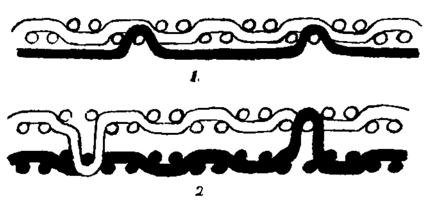

FIG. 57.—DOUBLE CLOTH INTERLACING.

1. Weft back. 2. Double cloth interlacings.
From Barker's *Textiles*, by courtesy of Constable & Co., London.

woven as double cloth, and are cut between the cloths, leaving a pile on each side (Fig. 58). Cotton velvets, corduroys, velveteens, and filling plushes are really varieties of double cloth. They are woven in a rib pattern, the cord being along the filling. The surface loops are cut by hand with a long cutter in the direction of the length. Cotton velvets require a great deal of finishing to make them look well. (See Finishing Cotton Goods,

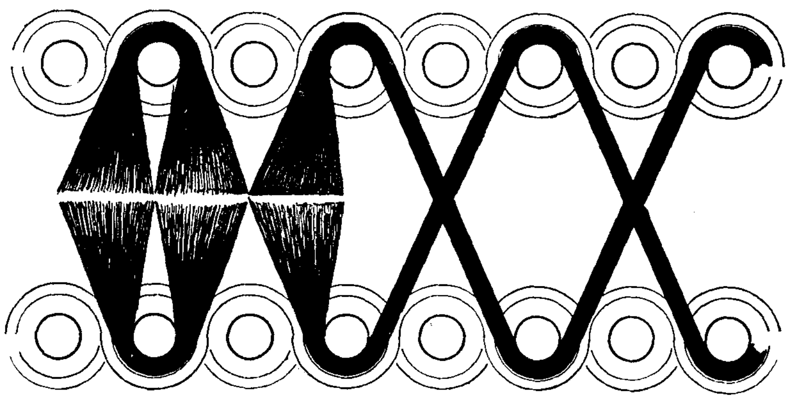

FIG. 58.—PLUSH WEAVE.

From Barker's *Textiles*, by courtesy of Constable & Co., London.

Chap. VII.) In their weaving the backing threads are brought forward to form part of the pile, and also to connect the two rows of warp threads. Different weaves are used to form the face and the back respectively, but the two must be designed to work in harmony with each other, or the finish will be defective. Crêpe or other crimped fabrics are woven in a variety of ways, plain, ribbed, or twilled. Some are made by using a sateen twill for the filling and a satin twill for the backing, the aim being to confuse the surface of the material by the way the stitches from the back break the face. Crêpe is also woven with the warp yarn twisted in one direction and the filling in the opposite. In the dye vat these yarns are differently affected and the cloth is inclined to cockle. They may be woven also with an extra special warp beam which allows the warp to be a little loose, while the threads on the regular warp beam are tight. When the filling is beaten up, the looser threads are rather full and the finishing gives them the crêped appearance. Wool crêpons are sometimes made with the backing threads of cotton. By mercerizing the material after weaving it, the floats of wool are drawn together by the cotton, which is contracted. Moiré or watered effects are made by the manner of finishing after the cloth is woven. The material is placed over hot milled rollers which are arranged to give a watered appearance to the goods.

Stitched, Backed, Double-faced, Double, and Multiple Cloths. — Looms are constructed to weave double and multiple cloths, but by special warps and double harness the regular loom can serve the purpose. Backed cloths referred to above are made by weaving them in such a way that extra backing warp is held by filling stitches to the face, making the cloth heavier. (For Draft see Fig. 69.) The stitch on the surface comes under adjacent face threads and is invisible. Double-faced cloths are made similarly to backed cloths, but are well finished on both sides, silk-faced ribbons being illustrations. Figuring on a plain surface by extra warp and filling threads is done in a similar way to the double-faced cloth, except that the design appears only at intervals. Cloths having long floats of warp or filling on the surface to carry out the design are made with a double warp or filling, and stitches come from the back to hold down the floats. Satin and sateen twills are much used for backing stitches. The double, triple, and multiple cloths have both double warp and double filling. They can be so woven as to be entirely separate, and when unfolded make a wide sheet of cloth several times the width of the loom, or they may be fastened together on one edge or on both edges and make tubular fabrics for bags, hose, or lamp wicks, or the two cloths may be held together at regular intervals and thus make reversible material for heavy coating and rugs. Backing yarn is frequently made of much cheaper fiber in order to decrease the cost while adding to the weight. Shoddy, coarse wool, and cotton are used for backing threads.

Design, Pattern, Draft, and Drawing-in. — Weaving may be very simple, with only an alternation of two sets of threads, as in cheesecloth (see Fig. 4), or it may be so complex that hundreds of changes are needed to complete the pattern, as when coats of arms or portraits of noted people are woven on Jacquard looms. When the hand loom could produce the intricate designs which we see in the Spanish, Italian, Sicilian, and Oriental cloths of the thirteenth century, a system of design was used to indicate the pattern, called drafting. A draft showed the weaver: first, the manner in which the filling should cross the warp; second, the entering or drawing in of the warp threads into the harness; third, the tying of the heald shafts; fourth, the treadling or succession in working the treadles. Figure 59 shows a common way of indicating to hand-loom weavers one variety of the diaper, bird's- or fish-eye pattern. The draft has therefore the following meaning: There are four heald shafts; *i.e.*, there are four straight lines representing the shafts, and four treadles are attached singly to each shaft. The method of entering, drawing in, heddling, or threading the heald shaft is shown in Fig. 59 *B*.

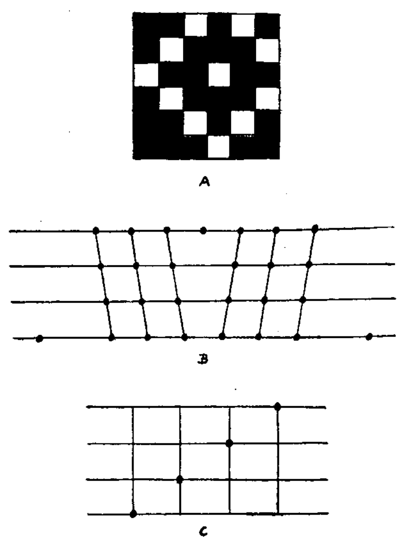

FIG. 59. — FISH- OR BIRD'S-EYE PATTERN.
A, Draft. *B*, Entering. *C*, Treadling.

The first heald of the first shaft takes warp thread number 1. In this same shaft will follow threads 5, 9, 13, 15, 19, 23; and thread 27 will begin the series again. The other warp threads are to be distributed in the other heald shafts as indicated. The treadles are fastened separately to the four shafts as shown in *C*. Every weaver has his own regular method of treadling, which he follows when possible, as it makes for speed. Elaborate patterns can be made by hand weavers from one set-up of the loom by different ways of treadling. In the early days of weaving each treadle influenced one heald shaft, but soon it was found that by tying the heald shafts together in various ways other effects could be gained. One shaft could work singly or in combination, hence, long before the power loom was invented, wonderful designs were made with even a few shafts. Two sets of harness were often used for controlling the warp. One set gave the background, the other the pattern. Damask of elaborate design was made in this way, having a twilled background and a complicated surface pattern. Each harness was used as needed, and the heald shafts hung free enough to be used singly or in combination.

Textile design may be structural (pertaining to the weave) or surface. Some varieties need have but a hasty mention, such as Oriental rug making, in which threads of yarn are tied around the warp thread and held together by filling threads, or embroidery in which the hand or machine makes the design on the completed cloth. The Swiss embroidery machines, the French Corneli, and the American Singer machine are illustrations of mechanical embroidery. The India shawl method of decoration, in which small, richly woven pieces are fitted together like a mosaic or like stained glass and sewed with a needle, is another instance. Surface decoration of textiles may also be done by the way of finishing the cloth, also by block or color printing by machine, either on cloth or yarn; by stenciling or batik work (Javanese method), or by discharge of color by printing designs on cloth with chemicals and then using heat to remove the color.

The principal structural method of ornamentation is by interlacing the threads; *i.e.*, by the way the filling or picks are floated, flushed or shot over or under the warp threads. To accomplish this interlacing the heald shafts carrying the warp threads through their mail eyes are lifted up, letting the filling pass under them; or depressed, letting the filling pass over them. In the first instance, the warp appears on the surface; in the second, the filling is on the surface. The varieties of pattern are attained by the manner of raising the sheds. Other factors may influence, such as the introduction of varieties of fibers, or different sizes or novelties in yarn. Even the plain weave may be thus ornamented, and effective ribs and cords given, or stripes either lengthwise or crosswise, by color alternations or checks and elaborate plaids. The omission of threads at intervals is also used to gain lacy effects. The great possibilities in design, and the elaboration of the draft to explain the intricate weaving plans, make the full study of drafting one for the expert. Fortunately, analysis of designs has yielded the fact that the chaos of patterns may be reduced to a few fundamental principles. In straight line warp weaving there is (1) the plain or tabby weave and its variations; (2) the twill and its variations; (3) the satin and its variations, including figure weaving (pile weaving, double cloth, and lappet weaving belong to this group). In curved warp weaving there are gauzes, lenos, and marquisettes.

In the designing and drafting for the weaving of textiles, whether by hand or power, there are two lines of threads to consider: first, the warp or ends, which run lengthwise of the goods; second, the filling, picks, woof or weft, which cross the warp at right angles. The manner in which the latter threads intercept the former makes the design, complex as well as simple weaving depending on the succession of sheds. In drafting for power weaving the work of the treadles is not indicated, as that is automatic. Textile designers use squared or point paper for their drafts; eight by eight is a common variety

(Fig. 60). The Jacquard design usually requires ten by ten or twelve by twelve. These papers also come lined to represent coarser threads one way than the other, which condition is often found in weaving by having a heavy filling and fine warp. In general the squared paper is preferred.

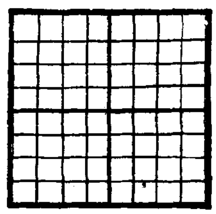

FIG. 60.—DESIGN OR POINT PAPER.

Ways of indicating the method of procedure on the paper in the draft differ slightly. In the accompanying illustrations the shaded blocks represent the warp threads and the white blocks show that the filling is on top with the warp underneath. The numbers when given at the side indicate the number of shafts or leaves requiréd by the weave.

The simplest alternation of threads is called the plain, tabby, or cotton weave. It is found in muslins, ginghams, prints, Panama cloth, and in some canvasses and broadcloths. India and taffeta silks and crash toweling also use the tabby weave. See Fig. 61 for the draft, which looks like a checkerboard. The numbers at the side show that under the first heald shaft a warp thread is up and then a filling thread, followed again by a warp thread. In the second shaft the filling thread rises first. Two alternations complete the pattern. When coarse yarns are in use, a two-heald shaft is sufficient. (See Fig. 62.) In finer yarns, four or even eight shafts are used (Fig. 62), as a better distribution of the warp threads can be made, thus lessening the strain and liability to break. The threads are so inserted and the shafts connected that they act as two, the odd numbered threads being raised at one time and the even at the other. There are variations of plain weaving which give considerable latitude in design. Basket or Panama weaves (Fig. 63) have two or more warp threads crossed by

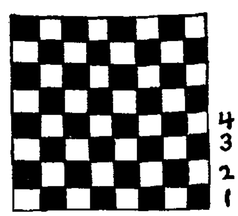

FIG. 61.—PLAIN WEAVE.

two or more filling threads, or there may be a greater number of threads one way than the other. Hair-line stripes, warp or filling way effects, can be made in the plain weave by alternating colored yarns in the warp and filling, or by alternating one way and having it plain the other. Bedford cords (Fig. 64) have a line stripe and raised cord effect running lengthwise of the cloth. The face effect is generally plain. Poplin or rep effects are made by very heavy warp threads or by groups of warp threads shot over by one or more filling threads (Fig. 65). The very twist of the yarn will affect the pattern (Fig. 66). If after interlacing the threads the twist is in one direction, a smoother effect results in the finishing.

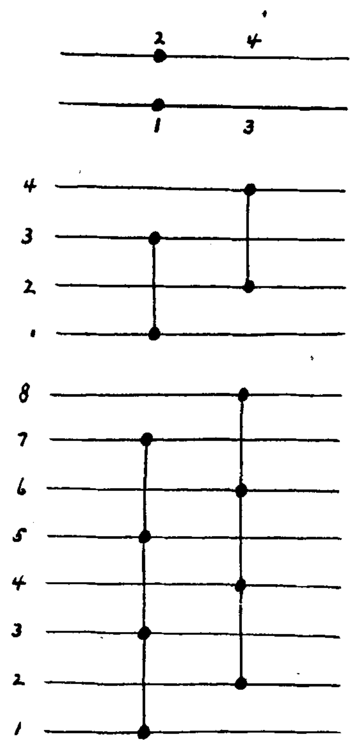

Fig. 62.—Shaft Combinations for Plain Weaves.

Twills are the first variation from plain design. The three-shaft, three-harness, three-end, or three-leaf twill, as it is variously called, is the simplest. (See Fig. 67 for four-leaf twill.) The names given to twills indicate the number of shafts which it takes to complete the pattern. In the three-shaft twill the filling threads go under one and over two warp threads in the first line, but instead of alternating in the second line, as would be done in plain weaving, the filling skips one thread to the right or left of the crossing of the preceding line, as the case may be, thus forming a diagonal line across the material. In the three-shaft twill, the pattern begins to repeat itself in the fourth line. Twills may run to the right or to the left or both ways. In the latter case the design is called chevron, herring-bone, diaper, bird's- or fish-eye. Twills may be so made that either warp or filling may be thrown on the face of the material. In the four-shaft twill (Fig. 67 *A*) the filling is on the face, for three filling threads are up and one down. In *B* the warp is on the face, as three warp threads are on the surface and one below; consequently the twill is made by the filling. For the warp-faced twill there would be three risers and one sinker on the chain of a head motion loom, expressed as 3/1. If it were a four-shaft twill, filling face, there would be three sinkers and one riser, throwing the filling on the face, and expressed by 1/3.

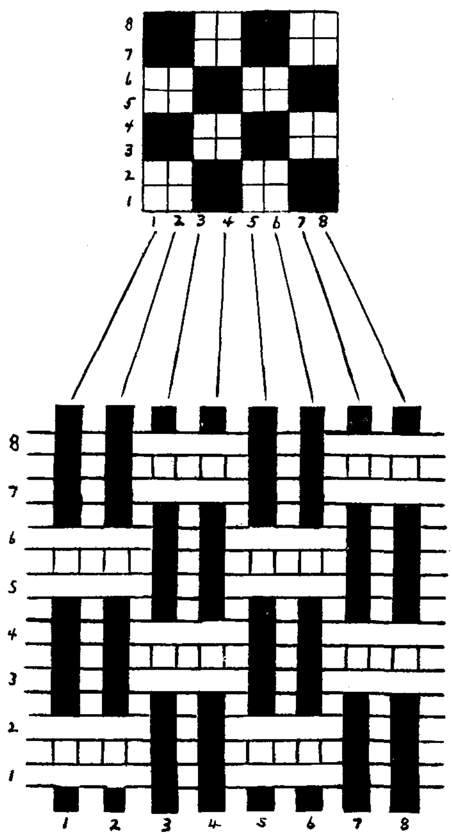

FIG. 63.—BASKET OR PANAMA WEAVE.

Drillings and jeans are often made on the three-shaft twill. Twills are among the most popular weaves. They may run as high as forty-eight or fifty shafts, each added number of shafts allowing a greater number of variations in the designs;

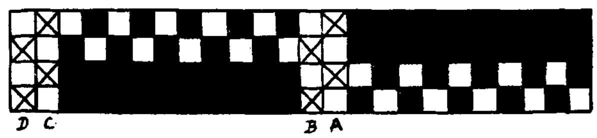

FIG. 64. — BEDFORD CORD.
A, *B*, *C*, *D*, plain weave throughout, forming line effect.

therefore it may be said that there is an almost unlimited possibility of pattern. Twills may be even-sided, filling and warp balancing; or uneven-sided, filling and warp uneven, each additional shaft having its own advantages and variations. The principle of designing for the twill can be understood from the simplest ones. The following varieties are in use: broken, skip, corkscrew, double, curved, combination, steep, wide-waled, entwining, checker-board, pointed, and fancy. The four-shaft twill is very useful in woolens and worsteds, being found in blankets, cassimeres, and shepherd's checks. It is much employed in double-backed and stitched cloths for the backing weave. The five-shaft twill is used extensively in heavy materials, in doeskins, satins and sateens, Venetians, drillings, diapers, and damasks.

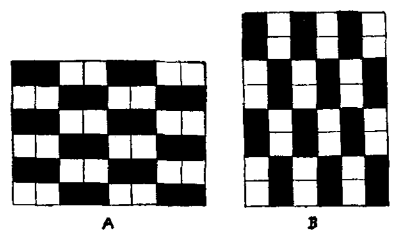

FIG. 65. — POPLIN OR REP.
A, Warp ways. *B*, Filling ways.

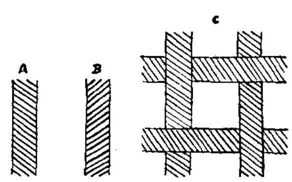

FIG. 66. — SHOWING TWIST OF YARN.
A, Left twist. *B*, Right twist. *C*, Combination.

Satin weaving combines the characteristics of the twill and the figure, and may be included under twill weaving as well as figure weaving. The term satin or sateen (Fig. 68 *A* and *B*) is used to designate certain classes of design, such as five-shaft or eight-shaft satin. These same terms are often used inter-

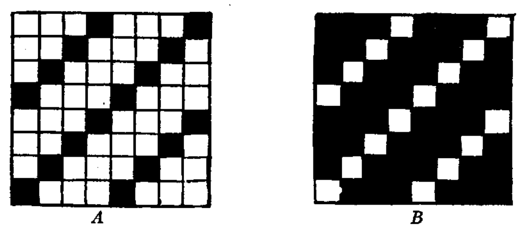

Fig. 67. — Four-leaf Twill.
A, Filling for face. *B*, Warp for face.

changeably, but according to some authorities the warp-faced design, *A*, is the real satin and the filling-faced is the sateen, *B*. The expression often seen, " weft-faced satin," would according

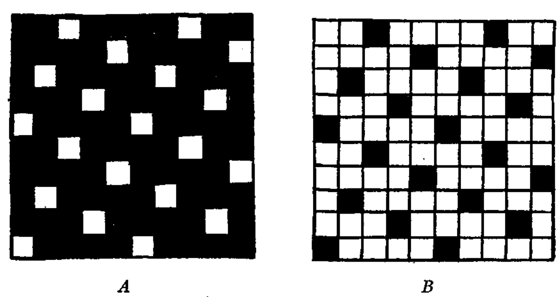

Fig. 68. — Satin Weave.
A, Real satin: warp face. *B*, Sateen: filling face.

to these authorities refer to sateen, and " warp-faced sateen " would be satin. The word sateen was first used for cotton satin made to look like silk satin. Damasks are often woven with the background sateen and the figure satin, that is, the figure weave is a lengthwise twill and the background a crosswise one. The corkscrew weaves are on one of these principles;

they are a steep twill. The twill effect is made clearer to the eye if it runs in the direction of the twist in the yarn. Smooth-faced serges are woven in this way, and the effect of clear light

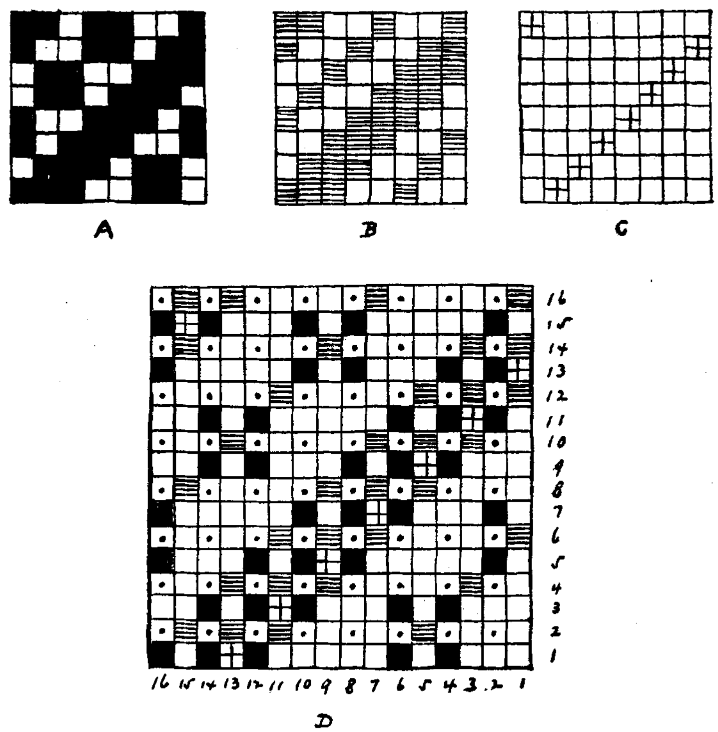

Fig. 69. — Double Cloth Weave.

A, Weave for the face. *B*, Weave for the back. *C*, Arrangement for combining back warp with face filling. *D*, The complete weave. Repeat: 16 ends; 16 picks.

is increased by the finish. Rough twills are often woven with the twist of the threads running opposite to the pattern. Twills of various kinds are used extensively in elaborate floral figures and conventional designs, as a binder or stitch to hold together the warp and filling threads, that too long floats will not be on the surface. Elaborate combination twills look like Jacquard weaving, but are really only clever repeats, alternations, or reversals of pattern.

The stitches used to hold together double cloths are usually twills which come at intervals to the surface. (See Fig. 69 for explanation of the method of drafting.) In some classes of worsted goods the binder is frequent. The stitching requires care in planning, so that it does not make itself evident on the face of the cloth. The stitching stitches are now frequently employed in all classes of patterns. Cheap stock is often used for them, as it gives weight and does not show on the face. Cloths backed with shoddy or poor wool are usually rough on the wrong side.

Satins or Figured Weaves. — The step between twills and figured weaves is short. Satin really belongs to both, for it is a broken or skip twill. The object in satin or sateen is to throw a series of closely twisted threads on the face of the material, with a cross thread at intervals, that the floats of warp or filling may reflect the light. When the warp is constantly crossed by the filling, the reflection of light is interfered with. In the satin the cross thread binds sufficiently to hold, yet it is not noticed. Cotton-backed satins save expense, and the cotton thread coming to the surface is not seen. When well woven of good materials this class of satin is enduring. An odd number of shafts is preferred for the satins; the five-shaft is much used, but the seven shaft is considered a perfect satin. Diaper patterns (Fig. 70) and spots are illustrations of simple figure

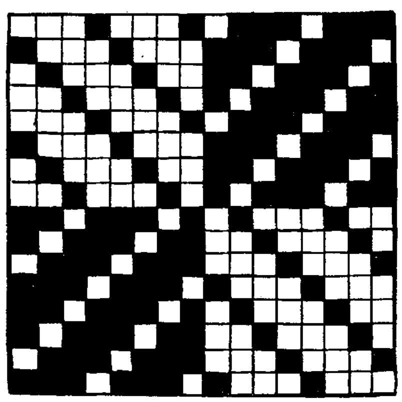

Fig. 70. — Diaper Pattern.

weaving, and Jacquard designs of intricate figure work. The damask designs are reversible, but brocades are woven with the patterns on the face only, though sometimes faintly indicated on the back. The filling threads which are not in use in an elaborate design are sometimes interwoven into the background until needed, and at other times are left in long floats on the back to be cut off in the finishing. Damask weaving is usually beyond the power of the simple loom, and the Jacquard harness is used. If the designer has a four hundred hook Jacquard and a cloth with one hundred threads in an inch, by dividing four hundred by one hundred he has four inches in which he must confine his design in width (the length is as he wishes it). He must avoid parallel and cross lines. Damasks are usually designed with warp satin and with weft satin or sateen for background and figure.

In figure weaving the background is generally a plain or satin weave. In designing, the relation of the pattern in the figure to the twill in the background has to be most carefully worked out, or the design will run into stripes or oblique lines. The number of needles in Jacquard weaving is also limited. The five- and eight-shaft satins for figure work are generally preferred by designers to the higher shafts. The use of color in silk designing brings in a large item of expense. As few changes as possible will reduce the cost of dyeing. The expense of the thrown silk is so great that computations of the amount of each color in a design have to be brought to the exact amount required, that nothing may be wasted. The silk designer must know these points. The design in Fig. 71 *A* is a lozenge or diaper pattern, with six changes in length and nine in width, used frequently in damask weaving. The complete diaper is made by a reversal. Fig. 71 *B* gives the arrangement of pegs in the lags for the dobby and Fig. 71 *C* the arrangement of the cards for the Jacquard harness. This design is a very simple one and perhaps would not be used on the Jacquard, unless an elaborate central or border design were included, but it

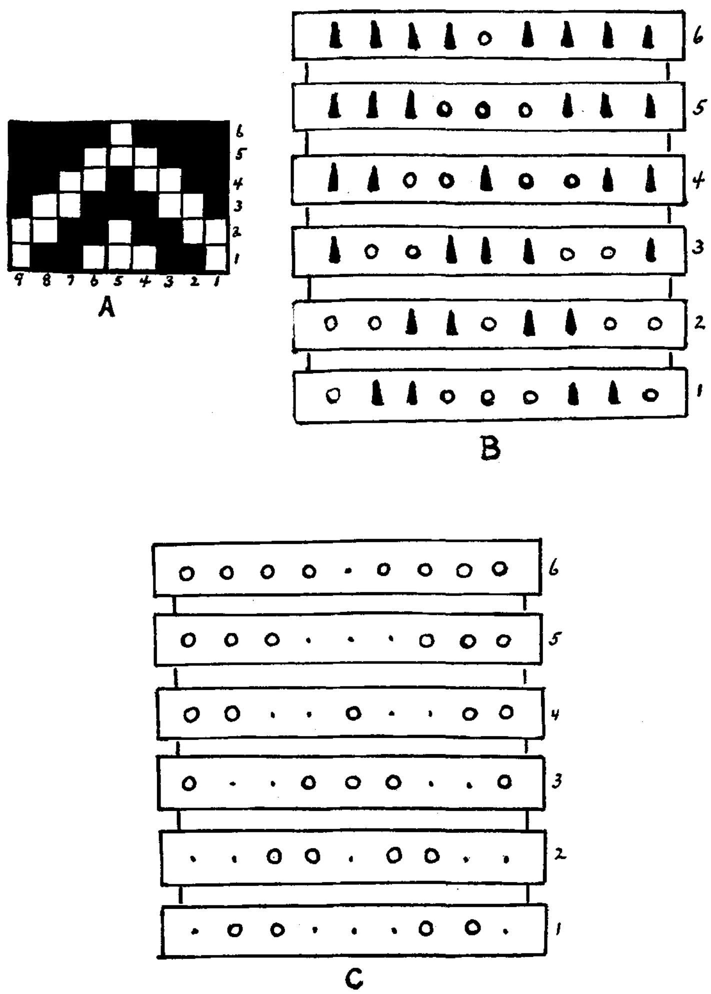

FIG. 71.—LOZENGE DESIGN.

A, Draft. *B*, Arrangement of pegs in the lags for the dobby. *C*, Arrangement of cards for the Jacquard harness.

illustrates the method of designing and preparing the cards. The numbers at the bottom represent the warp threads affected, and at the side the number of picks. In the cards the needles will pass into the holes and the connected hooks will remain on the griffes, but the other needles will strike the cards where the dots are, will be battened back, and the shed will be made by the hooks falling from the griffes; consequently in the first line the first, fourth, fifth, sixth, and ninth threads falling will make the shed and the filling will be uppermost, as seen in the design. The repeats of the pattern are provided for by the harness cords. In the lags of the dobby the pegs are inserted when the warp threads are to rise, consequently the filling passes under them. The first, fourth, fifth, sixth, and ninth will be down, and the second, third, seventh, and eighth up, which is what is required by the design. The repeats are controlled by the dobby.

Knitting. — Knitted goods are being used more extensively each year and include sweaters, underwear, hosiery, caps, gloves, neckties, and braids. The process of knitting differs from weaving, for the fabric is made by looping each succeeding line of thread into the one before it. Special machines of many varieties have been invented for the work (Fig. 72). Napped fabrics are made with a background of knitting through which soft yarns pass to the surface. Eiderdown flannel is an illustration. Knitting may be plain or ribbed, or both kinds may be found combined in one garment. Ribbed goods usually wear better, but they are more expensive. When the two varieties are used in one garment the article must be removed from one machine to the other, the loops being carefully transferred to the needles. Knitted goods when well made are enduring, but must be kept in good repair, for a broken loop will stretch quickly into a large hole on account of the readiness with which one loop slips out of another. Fancy knitted goods with open work and embroidery are made by special attachments or on special machines. Good knitted goods are elastic and firm to the touch, and have a fair finish. Mercerized and lisle thread yarns are used widely for knitted goods.

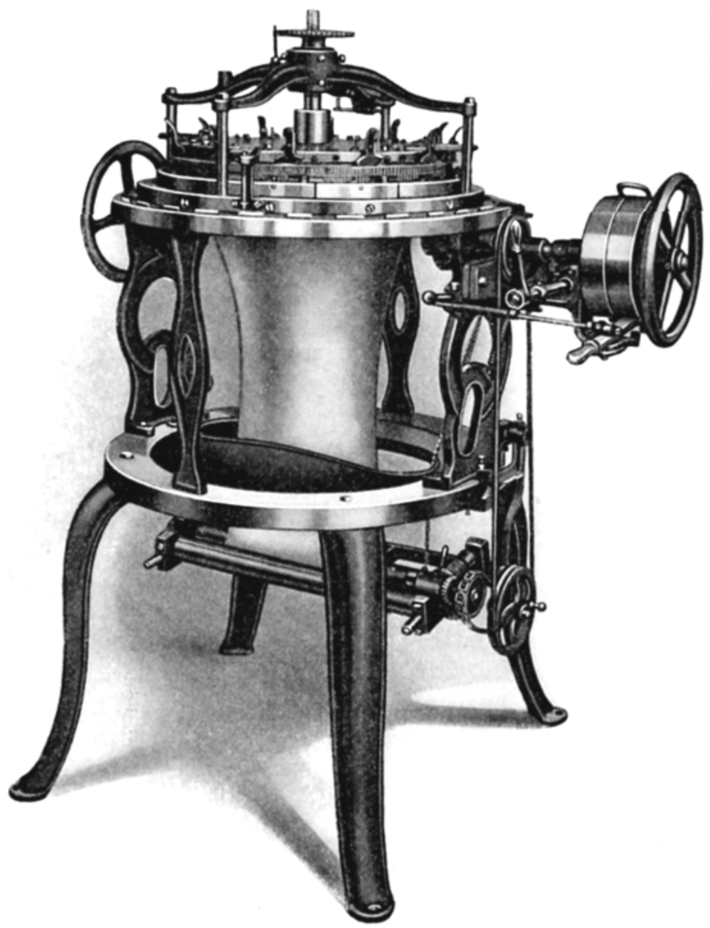

FIG. 72.—KNITTING MACHINE.

Knitting machines are circular in shape to make a circular article, or of a form to knit a specially shaped garment which can be cut and sewed together on a special sewing machine. The important part of these machines is the series of needles — the latch needle (Fig. 73), which opens and closes automatically, thus making the loop, or the spring needle, which accomplishes the same result in a different way.

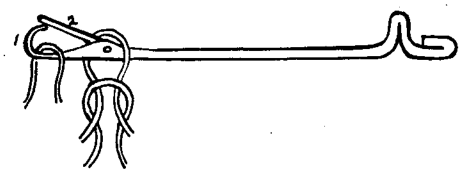

FIG. 73. — LATCH NEEDLE, SHOWING STITCH.
1, Hook. 2, Latch, moving on pivot.

Machines for sewing together the knitted pieces or for finishing necks or bottoms of garments, or for placing yokes of woven material on the knitted goods, are an essential adjunct to the knitting mill.

Methods of finishing by shrinking and steaming are very necessary in the final effect. The various ways of knitting stockings shows the method of these machines in producing inexpensive or costly goods. The cheapest hosiery is plain knitting made in a long tube on a circular machine, and lengths are cut from it. The stocking is finished by shrinking, cutting, and sewing the heel and toe into shape. A better class of seamless hosiery is made on a special knitter, and is finished by steaming, shrinking, and drying. The best kind of stocking is called full fashioned. The form of the stocking is made by a knitting machine in which stitches are dropped or taken up automatically, making the required shape. A special sewing machine unites the parts, and steaming and finishing follow.

The United States has many knitting mills, Pennsylvania, New York, and Massachusetts being the principal states.

CHAPTER V

WOOLEN AND WORSTED — RAW MATERIALS

Scope of the Industry. — Materials made from woolen and worsted yarns are among our most useful and valued textiles. The raw material is procured from the fleeces of various breeds of sheep, goats, and other animals living in all parts of the world. The cloths made from this wool or hair vary greatly, as the fiber ranges from the short staple, soft, crimpy, dull merino wool to the long, silky, lustrous wool of the Leicester sheep of England, the glossy hair of the Angora goat of Constantinople, or the long, coarse hair of the Chinese sheep. The length of the staple varies from two to twenty inches (Fig. 74). The fiber of most of the shorter wools is covered with minute serrations which are inclined to draw together when subjected to moist heat. This quality of shrinking or felting is utilized in making some classes of goods, such as doeskins and broadcloths. On account of these variations the industry may be said to include, in general terms: —

1. Materials made from soft, dull, loosely twisted yarn of uncombed, short stapled wool, such as blankets, sweater material, broadcloth, melton, kersey, and many flannels, which are generally termed woolens.

2. Cloths from carefully combed, long, more or less lustrous wool made into closely twisted yarn, and woven into serges, covert cloths, mohairs, worsted suitings, and diagonals, which are generally called worsteds.

3. Innumerable varieties of materials made from either long or short stapled wools, which are carefully combed, and combine, in varying degrees, clear surface patterns and felted face effects. This class offers many kinds of dress goods, suitings and flannels, knitted underwear, henriettas, and other more or less dependable goods.

A fourth division might be added, though it really belongs to the worsteds, *i.e.*, the coarse, hairlike, combed wools used in such heavy materials as carpets, rugs, and floor coverings.

The difference between woolens and worsteds was originally quite marked, for the short, serrated wools were used for the former, and the long, brighter varieties for the worsteds, but modern machinery can now comb the shortest staple wools, hence the difference is principally in the yarn preparation. The fibers which compose the woolen yarn are carded, but not

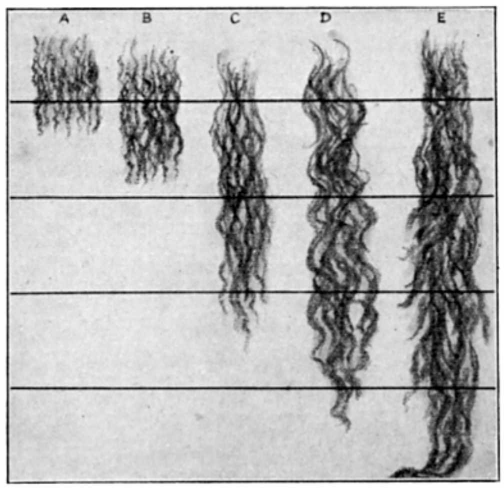

FIG. 74. — RELATIVE LENGTH OF STAPLE.

A, Merino.	Average length		$2\frac{1}{4}'' - 2\frac{1}{2}''$
B, Fine Crossbred.	"	"	$3''$
C, Alpaca.	"	"	$7\frac{1}{2}''$
D, Mohair.	"	"	$8''$
E, Lincoln.	"	"	$10\frac{1}{2}''$

combed, and cross and intermix irregularly, the appearance being soft and fluffy, and the preparation usually taking but a short time. The fibers, however, of worsted yarns are repeatedly carded and combed until they lie parallel and smooth, and are then closely and tightly twisted to make the yarn look regular and lustrous (Fig. 75). The preparation takes much longer than the carded woolen yarns, sometimes ten times as long. Woolen materials are usually soft, elastic, and of dull finish, and when they are felted the lines of weaving are more or less obliterated; while the true worsted cloth shows its pattern clearly from a firmly woven surface which reflects the light.

Value of the Industry. — In the entire world there were in 1912 about 627,000,000 sheep,[1] which contribute annually about $300,000,000 to the wealth of the world (Fig. 76). This includes the wool, pulled wool, and mutton industries. The countries producing the most wool were in round numbers: all Europe, 180,000,000 sheep; Australasia (Australia, New Zealand, and Tasmania), 117,000,000; South America, 110,000,000; North America, including Canada, Mexico, Porto Rico, and Philippines, 59,700,000; Africa, 51,000,000 (Fig. 77). The main countries consuming wool were the United Kingdom, 492,000,000 lbs.; United States, 480,000,000 lbs.; France, 457,000,000 lbs.; Germany, 380,000,000 lbs.; Austria-Hungary, 132,000,000 lbs.; Italy, 57,000,000 lbs. Fig. 78). The wool industries and their connected occupations are of prime importance to the ruling nations of the world. In 1912 there were about 39,000,000 sheep of shearing age in the United States, representing more than one half a billion dollars. The wool on these sheep amounted to about 300,000,000 lbs. This was about two thirds of the wool used in the mills of the United States in that year.[2] It can be seen that the growth and manufacture of wool are large items in the prosperity of our country. For various economic and political reasons the production of wool has decreased in the past few years, which condition may or may not continue.

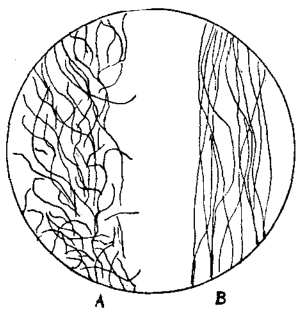

FIG. 75. — SLIVER OF WOOL AND WORSTED.

A, Wool. *B*, Worsted.

Although sheep are grown for both mutton and wool in most

[1] Bull. National Association of Wool Manufacturers, 1912.

[2] Much of the data has been taken from "Schedule K," Report of the Tariff Commission.

of the states, the great sheep-raising states are west of the Mississippi. The breed is generally merino of more or less full blood, but some long stapled wool is grown, and even the long

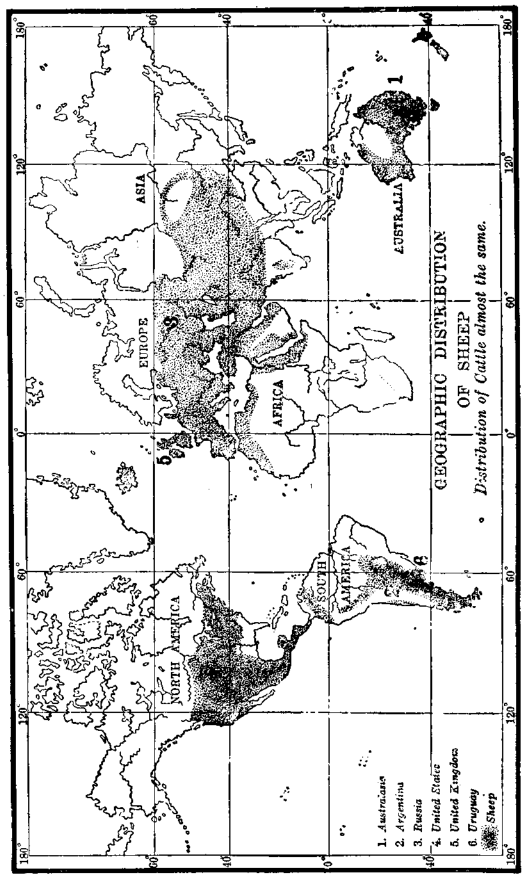

FIG. 76. — SHEEP-RAISING SECTIONS OF THE WORLD.

From Tarr & McMurry's New Geographies, Second Book, 1910, by courtesy of the Macmillan Co.

haired angora goat is cultivated. In the manufacturing of wool the leading states in 1911 were Pennsylvania, Massachusetts, Rhode Island, and New York.

Nature. — The woolen and worsted industries use both wool and hair. (See Chaps. XI, XII for physical and chemical structure.) Some wools have a great number of serrations, or scales, but these are rudimentary or apparently lacking in others. In manufacturing woolen cloth the wool having the most serrations

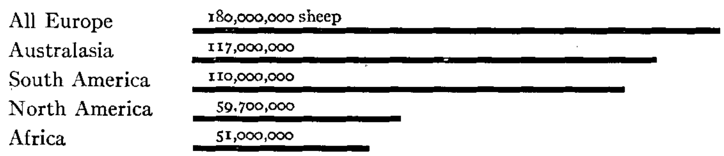

FIG. 77. — PRINCIPAL WOOL-PRODUCING COUNTRIES.

is desirable, but for worsted suiting the long, glossy wools with few serrations are best. Some serrated wools are lacking in felting qualities.

Desirable Qualities — Conditions Affecting Wool. — The qualities desired in the best wool for the manufacture of dress goods and suitings are present when the breeding, cultivation, and care of the sheep have been of a high character. These depend on climate, soil, food, and the crossing with other

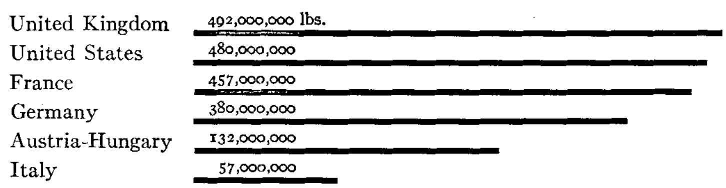

FIG. 78. — PRINCIPAL WOOL-CONSUMING COUNTRIES.

breeds. Careful wool buyers look for the trueness of breed which gives a clean, fine, sound, even growth of wool, full of vitality and elasticity. There should be no kemps or coarse, hairy fibers. The luster and length should be adequate in long staple wools, and the crimp and curliness in felting wools. Uncared-for sheep which roam at will on the plains and mountains develop coarse hair in their wool, but cultivation tends to increase the soft wool around the roots, and to eliminate the coarse hairs. The health of the sheep is quickly affected by climatic conditions, food, water, and incidents of life. When these factors are good a natural oil or yolk secreted in the skin gives softness and vitality to the wool. A very cold winter, though hard on the sheep, often develops a heavy fleece, but when the climate is harsh and the rainy season prolonged, the yolk is apt to be washed out, consequently the fiber grows unevenly and is likely to be brittle. Wool from poorly bred sheep is apt to be tinged in color and does not spin well; the dead hair will not take the dye, and cloth made from it wears unsatisfactorily. When the climatic conditions are good, the quality of the wool and its soundness depend on the herder's or shepherd's care and knowledge. The very soil has its effect. Sheep crop very close and must be moved frequently. Some soil tends to weeds, and the wool will gather the burrs; others bear poisonous plants which injure the health of the sheep. The herder must keep the flock calm and well fed, he must see that the feeding is regular between seasons, and must lead the flock to shelter when extremes of heat or storms menace. The well-trained shepherd and his ally, the sheep dog, are almost as important in the final condition of the cloth as is the superintendent of the mill with his heavy responsibilities. It is only when the environment and life of the sheep are satisfactory that the important qualities of trueness of breed, soundness of fiber, strength, softness, fineness, length, and pure white color are attained. The shrinkage of wool is also an important consideration. The carpet industries require the long, tough, enduring, hairlike wools. The sheep which provide these wools are hardy animals, and their long, hairy fleeces are a protection in their battle with nature.

Properties. — Wool possesses properties which on the whole make it our most valued textile for all climates.

Absorbing Moisture, or Hygroscopic Property. — Wool is capable of slowly absorbing a large amount of moisture and of holding it between its cells and in the very center of the cells. Under ordinary conditions it takes in from twelve to seventeen per cent of its weight, but when exposed to very damp air it will absorb as much as thirty to fifty per cent, thus making it much heavier. The legal amount of moisture at present is seventeen and one half per cent. Those who wear greatcoats of wool have perhaps noted the increase of weight when they have been exposed for some time to a very damp atmosphere. The hygroscopic quality affects its handling, for the weight of a certain amount of wool will vary under different conditions, and the weight will affect the price. Deceit can be practiced, and moisture-absorbing substances are often added to wool that a higher price may be received for it. Conditioning houses have been opened for the benefit of the community, to determine whether a given lot of wool is standard weight, and also if its condition is as pure as represented.

Felting or Shrinking. — Most varieties of wool are covered with minute scales or serrations composed of gelatinous material, which softens under heat and moisture. If pressure is brought to bear, the serrations are locked together permanently, and the cloth is shrunk, *i.e.*, reduced in width and length, and thickened.

Tensile Strength. — Wool is high in tensile strength, although the quality varies in different classes of wool, in parts of the fleece, and with the size of the fiber. Carefully manufactured cloth of pure wool is a strong, reliable material.

Elasticity. — Natural wool is very elastic, as may be noted if a lot of it in the raw state is pressed in the hand. Elasticity adds to the strength of cloth, and to its comfort as a covering for the body, but this quality is impaired by careless manufacture or laundering. An instrument called the dynamometer is used to test wool for strength and elasticity.

Electricity. — Wool is a good generator and a poor conductor of electricity, qualities which are advantageous in clothing.

Wool- or Hair-bearing Animals needed in the Woolen and Worsted Industries. — The fleeces of many varieties of wool- or hair-bearing animals are used in the manufacture of woolen and worsted cloths (Figs. 79, 80). In a very general way wool or hair (the term wool is used to cover both) may be divided into two groups: short staple wools, the fiber being from two to

FIG. 79. — AMERICAN MERINO RAM.

From Collins' *Woolen and Worsted Spinning*, by courtesy of the American School of Correspondence.

four inches, and long staple wools, the length of fiber being from four to ten or even twenty inches. (See Fig. 74.) Some wools occupy a middle ground.

The various wools and hair now used in the wool and worsted industries of the United States fall fairly well under the following headings: —

1. Merino (Rambouillet breed is used extensively in the United States).
2. Crossbreeds from the merino and other sheep, notably the Lincoln.

3. Pure blooded coarse- and long-haired sheep such as the Lincoln and Leicester.
4. Coarse wools from the sheep of China, East India, Turkey, Russia, and other countries.
5. Hair. Mohair, alpaca, camel's hair, and others.

The Domestic Clip. — The United States in 1912 grew about two thirds of the wool used in its woolen and worsted mills.

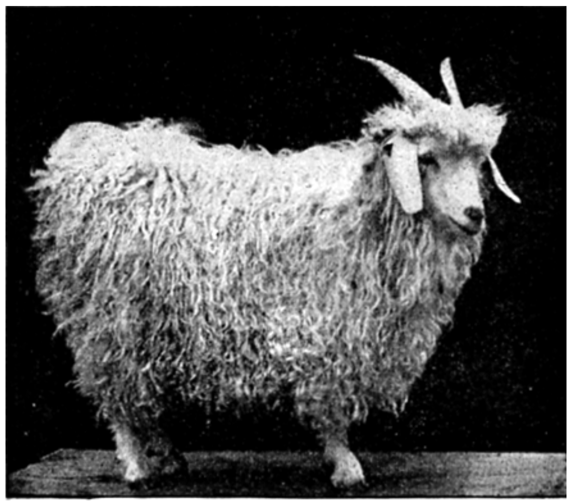

FIG. 80. — ANGORA GOAT.

From Collins' *Woolen and Worsted Spinning*, by courtesy of the American School of Correspondence.

Sheep are raised in most of the states, the mutton industry being often more important than the wool. New England breeds most of its sheep for food; the Middle States, of which New York had 625,000 sheep (April 1, 1912,[1]), subordinates its wool to its mutton. The South also inclines more to mutton breeds. The upper Ohio valley grows some of the finest merino wool equal to the Saxony, but the expense of raising is great, and mutton grow-

[1] Bull. National Association of Wool Manufacturers, 1912.

ing is as important as wool. The middle western states have over six million sheep, but the wool again is a side issue, for they are also kept for mutton, for scavengers, to destroy weeds, and to eat what would be otherwise wasted, to distribute valuable manure, and to improve the appearance of the farms. The sheep thus saves labor, eats waste, and yields good profit.

It is in the far western states that sheep growing for wool is most important. In the southwestern states, Texas, Arizona, New Mexico, and Colorado, sheep raising is the most important industry, and the range merino the principal breed. The climate and conditions are more favorable than in the northwest. California has different conditions from either the southwest or the northwest states, and its wool is listed by itself in market reports. Texas and Oregon are also sometimes listed separately in the same way.

In the northwestern states, Idaho, Wyoming, Montana, Utah, Nevada, Washington, and Oregon (Wyoming and Montana having each about 4,000,000 sheep), American labor is used in general, and wages are high, for there are competing interests. There are many varieties of sheep, and the mutton industry is also a factor.

In the United States the principal breed is the merino (Rambouillet) (see Fig. 79), which, in general, belongs to the short staple group. Selection and crossing with other grades of sheep have developed a longer staple.

Three groups are commonly given in the market quotations: (1) Fleeces (washed) grown on farms in Ohio. Pennsylvania, West Virginia, Michigan, Wisconsin, and New York, which have fine, not very long, staple wool sometimes equal to the Australian in fineness and felting quality; (2) Bright wool which is coarser, longer staple with much luster, from Missouri, Indiana, Maine, New Hampshire, Vermont, Kentucky, and other states. These wools are cross bred with merino, and according to percentage of crossing are spoken of as $\frac{1}{4}$ blood, $\frac{3}{8}$ blood, $\frac{1}{2}$ blood, and $\frac{3}{4}$ blood. They are marketed both washed and unwashed. (3) Territory wool includes sheep of all grades grown in far western states such as Montana, Wyoming, Utah, Idaho, Oregon, etc. This last class is usually marketed unwashed, hence the shrinkage at the mill is very great. Some of it is sold on the scoured basis. A few special wools are quoted outside of these groups, such as California, Colorado, Texas, and New Mexico. Some of these wools are marketed scoured, and are clipped twice a year, consequently send very short wool to market. Delaine is a longer staple than the ordinary merino, being developed by selection in breeding. It is taken from selected merino fleeces and is grown all over the United States. Lake (Louisiana) and Georgia wools really belong to the second group, but are listed by themselves. Various designations for fineness are given, such as Nos. 1, 2, 3, 4; the first being the best; or fine, fine medium, and medium, or choice, good, average, and others.

The Growth and Care of the Sheep. — Methods vary in different parts of the United States, but the following may be taken as fairly representative of the life on the northwest ranches. In 1912 in twelve of the Rocky Mountain states there were 20,000,000 sheep, of which about one fifth were run on government land. This is changing, for agriculture is coming in rapidly in some sections, driving out the sheep ranch. The cost of forage is high, if the sheep are fed on the ranches. Water is often scarce, owners are fencing in their water supplies, and conservation of forests prevents the herder from grazing his sheep at will. Whole flocks are often lost by cold, storms, poisonous plants, predatory animals, and other causes. On these great western sheep ranches as many as 60,000 to 100,000 sheep are owned by one man. These are divided into a number of flocks, the average size being 2500 sheep under a herder. The fact that sheep so easily follow a leader makes it possible for one man and a trained dog to control thousands of animals where limits in fences or hurdles are unknown. The herder is given his provisions, and in addition is paid from $40 to $50 per month. The sheep ranches have their camp tenders, each of whom is responsible for two or three herders. They supply the latter with food, magazines, and books every few weeks, and move the sheep wagon if necessary.

The cool nights in these western mountains clothe the sheep in heavier coats than in the South. A good dense fleece, the conformation for good mutton, the ability to herd in large flocks, yet to keep together on the feeding ground, are points desired in these sheep. The snow will cover the grass for days and the sheep will suffer from hunger, which if it does not kill the sheep will injure the wool, producing weak places in the fiber which will break in the spinning. If the land is weedy, burrs catch in the fleece and injure its sale, for they can only be removed by machinery or carbonizing. Insufficient feeding between seasons or poor food at any time injures the growth of the wool and tends to leave it harsh and dry. The flockmaster, in spite of careful preparation, may have all his calculations upset by a severe winter. Entire flocks are often lost or the wool permanently injured by extremes of climatic conditions.

The flocks are composed mostly of ewes, the wethers being sold young for mutton. The average price of one sheep on a western ranch, although it changes from year to year, is $5.20. Lambs are worth $2.00 from the fall after their birth. The shearing life of a sheep is about five years. When a ewe is too old for shearing she is fattened and sold for mutton.

When the shearing season comes the flocks are brought to the shearing pens which are usually near the ranch house. The large ranches make preparations for conducting the shearing at their own pens, and the dipping in their own troughs. A good worker can shear in one day from 100 to 200 sheep, and receives about ten cents per head, the average amount made being $12 per day. The heavy merino sheep takes longer to shear than the others, such fleeces having even weighed as much as thirty pounds. The average is from five to twelve pounds " in the grease."

Unless the shearer is careful he will cut the skin of the sheep, which not only causes suffering but also interferes with the even growth of the fleece. The usual method is for the shearer to throw the sheep on its haunches, clasp it between his knees and hold it with one hand while he uses the shears with the other. He cuts in circles from the neck or shoulders down to the tail (Fig. 81). The wool holds together and is stripped from the sheep in a complete fleece. The shearer rolls it in a bundle. In large flocks the sheep are next branded on the back or side with the owner's mark. Complaint is constantly made by wool buyers of the careless use of paint in branding, which injures the wool, making some of it worthless for spinning. After branding,

FIG. 81. — MACHINE SHEARING.
Courtesy of the Chicago Flexible Shaft Company.

the sheep are often dipped in an antiseptic solution to free them from parasites and disease. In some of the western states this is required by law.

The fleeces are taken to the wool packer (jamber) who sits on top of a wooden rack or framework (like a very high stool) which has a long bag hanging down in the middle of it, and a shelf at one side to hold the wool thrown up to him. The packer drops the fleeces into the bag and treads them down. One bag holds about forty fleeces, and weighs from 250 to 300 or 400 pounds. Unwashed wool in the west ranges from the low price of 10 cents a pound to the good price of 20 cents or the high price of 22 cents or more. In general, a wool that costs 16 to 18 cents a pound in the west is worth about 20 to 22 cents a pound in Boston, the principal wool market of the United States, and the cost when scoured would be 55 to 57 cents per pound, due to the increased amount of wool needed to make a pound. About 35 pounds of clean wool are obtained from 100 pounds "in grease."

When wool is sold in the grease it shrinks greatly in weight from the scouring process, — usually more than one half. Wool buyers can estimate with much accuracy what shrinkage will occur in scouring, although it varies greatly with the quality of the wool in different places. Foreign wool shrinks less than ours. Good western wool often shrinks from 63 per cent to 73 per cent; the average shrinkage is 62 per cent. The average shrinkage of fine merino wool imported into the United States from Australia and South America is about 48 per cent. The average English long-combing wools shrink a little over 21 per cent. The advantage of washing before shearing is that the fleece is whiter and the cost of transportation is less. The disadvantage is the brittleness of the wool on account of the lack of oil in it. Merino and crossbred fleeces imported into the United States, are, as a rule, "skirted" before shipping; *i.e.*, the poorest and dirtiest parts are trimmed off.

The marketing of wool falls under the following heads: —

1. Sold to dealers in raw wool.
2. Sold to the mills direct.
3. Purchased by order from foreign countries.

Boston, New York, and Philadelphia are the principal cities of the United States for the sale of raw wool. The wool merchants in those cities, who are the middlemen between the grower and manufacturer, send their buyers west about the first of the year to purchase wools. They visit the various ranches and learn conditions of the clip. The wool bought is sent east soon after it is cut. It does not go directly to the mills but to the wool merchant, who usually buys it on a scoured basis, that is, the buyers have estimated the shrinkage which will occur in any one wool, and pay for the raw wool minus the shrinkage and a few other charges such as freight and packing. The ability to judge the shrinkage of wool is an important asset for a good buyer. The wool usually comes east with all the oils, dirt, and waste in it. Consequently the freight is heavy and the packing costly. On arriving, the bags or bales are taken to the warehouse of the merchant or placed in public storage. The greater part of the wool is sorted after arriving, and placed in piles or bins from which the manufacturer chooses the variety he desires. The merchants usually specialize in certain classes of wool.

The Wool Supply.[1] — The merino sheep, originally from Spain, is the progenitor of many of the world's noted flocks. The Saxony and Silesian sheep of Germany are of the merino breed, and give the finest felting wool in the world. Merino sheep were early imported into the United States and were the basis of the present flocks. This wool is valued for its softness, warmth, and felting qualities, and is used in broadcloths, flannels, cashmeres, soft serges, suitings, and dress goods generally.

The Australian sheep are also to a large extent merino or crossbred merino stock. This wool ranks high for felting qualities, often equaling the Saxony. Australian wool costs little to raise, on account of favorable climate, abundance of food, cheap labor, and profit on mutton. It is estimated that ninety-three cents will cover the cost of raising one sheep in that country, while in South America it costs $1.15, and in the United States $2.11 per head.

In 1909 there were 718,527,132 lbs. of wool produced in Australia at a value of about $139,125,000. There is promise, in some sections, of increasing sheep raising, though in other instances agriculture is taking the place of pasture land. In 1910 there were about 100,000,000 sheep in Australia. The

[1] Data from Schedule K.

United States buys largely the Australian clothing wools and also some of the combing wools. Our market grades them as choice, good, and average. The principal ports for wool shipment are Sydney, Brisbane, Melbourne, and Adelaide. The great annual wool sales between September and April are attended by trained buyers from all the important wool manufacturing countries of the world. The Sydney sales of merino wool even threaten the supremacy of London, and in 1909–1910 represented a value of $55,000,000. As the sales in London are held the year round, many of the United States buyers find the English market better for them.

Great Britain (England, Ireland, Scotland, and Wales) grows both long and short staple wools. The climate is especially favorable on account of the mildness of the winters, the coolness of the summers, and the excellence of the grass and forage crops. Parasitic life, which in warm countries causes losses among the sheep, is little felt. In the sheep raising in Great Britain the production of mutton and the fertilization of the land are more important than the wool crop. The farmers are students of breeding, and produce many types of sheep, most of them for the dual purposes of mutton and wool. The sheep and lambs in 1910 numbered 31,000,000.

Great Britain has developed many noted breeds of sheep which grow long, lustrous wool, especially desired in the manufacture of fine worsted suitings. The Leicester is one of the oldest, and has white, shining, curling wool often twelve inches long. It has been much used for crossbreeding and developing other varieties. The Cotswold, with fine fleece less lustrous than Leicester sheep, is much used in western United States for crossbreeding with the range merino. The Lincoln, with very long staple, lustrous, heavy fleece, is used for bright serges, dress goods, braids, and coarse goods. This wool is too coarse for more than a limited use. Another long-wooled sheep is the Romney Marsh, similar to the Lincoln, but with less lustrous wool. Various other types of sheep produce wool of the long staple variety. The pure bred Cheviot, which has a soft wool of three to four inch staple, is found in South Scotland and in North England. The wool comes between the long and the short staple varieties. These sheep and the Leicester have been crossbred with the Highland sheep of Scotland, and have produced a type of wool from three to five inches in length, used in making cheviot cloths and high class tweeds. Wools of medium length are clipped from the Downs. These sheep grow principally in the central and southern part of England. The wool is fine and soft, and is used for hosiery and flannels; the longer staples are used for cloth. These sheep are noted for their mutton. The Southdown and the Suffolk are the finest, but the Oxford and Hampshire are good; the Shropshires are classed with the Downs, and the Dorset is very similar.

South America is second in importance to Australasia. Argentina, Uruguay, and the island of Tierra del Fuego are the most important sheep runs. Uruguay will long remain pastoral, but Argentina is giving up sheep runs for agricultural enterprises. The Uruguay wool is sometimes sent direct to Europe, but usually to Buenos Ayres, which has a big wool market. It is here assorted and sold for export. As a whole the wool is fairly dry and clean, but heavy with sand. The light shrinking wools are purchased by the United States in large quantities.

The New Zealand wool, of which much is purchased in the United States, is noted for its good color and for its sound, soft feel. The staple is rather long, with freedom from imperfections. This wool shrinks little, and is free from sand and dirt.

South Africa has 30,000,000 sheep, of which 19,000,000 are in the Cape Province. The climate is fairly good, similar to the American southwest, and periods of dry hot weather with drought are followed by fine rains and good feeding. The flocks suffer from predatory animals and disease. Most of the sheep are of merino stock. The best Cape wool is snow white in color, and is used in the finest dress goods.

There are many other classes of wools which are used in the industries. For the coarse wools, largely for carpet yarns, Russia produces the Donskois, which have long staple. From Central Asia we buy a number of coarse, similar wools, such as the Bokhara, Afghan, and Khorassan from Persia. From Syria we buy the Aleppo, Orfa, Damascus, and Jaffa. From India we obtain a number of wools called in general East India. Some coarse wools from various countries are also used in combination with finer clothing wools.

Canadian wools are in general shorn from English long-haired breeds, and are used in the United States for combed yarns, although there are also some merinos and crossbreeds from Canada used for carded yarns.

Wool from Adrianople is pulled from the skins of sheep killed for mutton. Several kinds are often combined in one bale; they are used for both clothing and carpets.

The mohair wool, taken from the Angora goat, is very long and silky, and from four to ten inches in length. It hangs in ringlets on the sheep. It is used largely in the manufacture of plushes and lustrous dress goods. Originally a native of Asia Minor, the Angora goat is now raised in Turkey, the Balkans, Cape of Good Hope, South Africa, parts of the United States, and Tasmania. The staple varies in length from seven to fifteen inches; it is strong and has luster. It is used for linings and dress goods. The alpaca, or Peruvian sheep, is a species of llama.

Cashmere wool comes from the cashmere goat of Thibet and the Himalayan mountains. The fleece has long, glossy outer hairs and a soft under down of wool, which is shed or combed from the goat in springtime and called cashmere. It is silky to the touch and grayish in color. The amount from one goat is small.

Camel's hair is also used to some extent. The best is from the interior of Asia Minor from the Bactrian camel, and is shipped to China, sold, and manufactured into clothing. The Russian camel's hair is strong and long, and is used for bagging and coarse yarns.

Wastes and Substitutes. — The world's wool supply is insufficient to make all the cloth demanded, consequently pure wool in the raw state is costly and substitutes are used in order that the material may be sold at a price within the means of the people. The United States imports much of its pure wool, but little of the wool substitutes at present. However, it obtains sufficient wastes from the home market, and the reclaimed wools are largely used in cloth production. The manufacturer of woolen goods uses noils [1] from the combing machines, waste from cards and other machines, coarse, hairlike wools, pulled wool from dead sheep, extract wool, shoddy, mungo, cotton, ramie, jute, and silk noils to combine with the pure wool. Worsted manufacturers use noils, waste from worsted manufacture, pulled wool, coarse, hairlike wools, and some cotton, although it does not combine well with long combing wools.

The occupations connected with the collection and preparation of wool wastes have become very important. Rag markets are held in many countries. Germany has several noted ones, and some of the wool waste markets in England are perhaps the largest in the world. Shoddies, mungoes, mechanical wools, cheap clothing and cloth are taken there and sold in large quantities. America sends shoddies and wastes to the German rag markets. New York City is a center for the clothing trades, and many are occupied there in the rag industry. Old clothing and rags are collected, the buttons and seams are cut off from the clothes and the cloth is graded according to color and quality and sold in lots. These rags are beaten by machinery to free them of dust and later are fed to revolving cylinders armed with teeth which tear the cloth into a fibrous condition. The machine wastes are sold directly from the factories. When rags of cloth made of wool mixed with cotton are to be utilized, the cotton is removed by carbonizing before the wool is used again.

[1] Terms unfamiliar to the reader should be looked for in the Glossary at the back of this book.

CHAPTER VI

WOOLEN AND WORSTED — MANUFACTURE

It has been said that the manufacture of wool requires more brains than other industries. From the beginning of the mill processes to the turning out of the finished product conditions may arise to injure the cloth and reduce profits. The one responsible for the result must have a practical knowledge of mechanics, of chemistry, and of design, color, and weaves. He must know the qualities of both foreign and domestic wools, that he may select the right kind and color for his varied purposes. He must have experience in selecting wastes and substitutes to combine with the pure wools, that his recipes may be satisfactory and that the best results in cloth at the lowest price may be obtained. Having selected his raw stock, he must next watch the various processes of manufacture to see that the wool shows the right reactions and results. Each step, from the raw stock through spinning, weaving, and finishing, has its special difficulties, by which the product may be weakened or marred at any point. Machinery must be watched, or some trifling lack of adjustment will cause it to wear out too rapidly. Aprons, brushes, and other necessary parts will give better service, if special care is exercised. Oil stains, difficult to eliminate from wool, may occur through carelessness. Wool requires a humid, warm atmosphere, or the natural electricity becomes too high, yet it is hard to maintain the best condition without expensive apparatus. Dangerous dust and gases must be removed for the protection of the workers. Ventilation must be constantly considered, new labor-saving devices tried, and all waste and by-products must be utilized to the best advantage.

The superintendent must be keen as to efficiency and economy at every turn, yet must make a product which will please a fickle market.

Woolen and Worsted Spinning. — Preparatory processes for both woolen and worsted yarns are similar, the machines used differing only in their adjustment to long or short combing wools. The practice is increasing of putting several machines in a train or series by which the wool passes automatically from one to the other and saves handling. Each mill has its own method of procedure which has grown up through experience. Unwashed wool contains a fatty or greasy matter called yolk, which has been secreted from the skin of the sheep, and dust, dirt, burrs, and straws cling to the fleece. If the wool is fairly clean, scouring alone is required to prepare it for carding, but if it is full of impurities, it must be dusted and opened before scouring is advisable, and carbonizing must follow scouring when the wool is full of burrs. If the mill makes woolen yarns, the processes aim to clean but not to lay the fibers parallel in the yarn. On the contrary, worsted yarns must be repeatedly combed, that the fibers may lie side by side before they are twisted. It is impossible, therefore, to present a series of processes which are regularly used, but the general practice may be outlined as follows, although conditions constantly change with new inventions: —

PROCESSES COMMON TO WOOLENS AND WORSTEDS

1. Sorting or dividing into qualities; classing.
2. Cleaning, usually required to some extent.
   Opening, when wool is matted and very dirty.
   Dusting, for dirty wools.
3. Scouring, for greasy or half-washed wools. There are usually three baths.
4. Dyeing in the wool or raw stock dyeing, used often with woolens. Dyeing sometimes follows burring by carbonizing, if the color will be injured by the chemicals.
5. Drying.
6. Burring. Needed when wool is full of burrs, which is frequently the

case with short staple wools. There are two methods of removal: (1) by machinery; (2) by carbonizing. Sometimes a burr roller attached to the carding engine is sufficient.

7. Blending or mixing the various kinds of wools needed for a particular yarn.
8. Oiling (sometimes done before blending).

PROCESSES FOR SPINNING

A. Woolen or Carded Yarn.

1. Picking. For opening, cleaning, and mixing. Sometimes the wool requires several of these machines.
2. Carding. Usually three machines in train. American names: (1) First Breaker; (2) Second Breaker; (3) Finisher. English names: (1) Scribbler; (2) Intermediate; (3) Condenser. The wool is frequently ready for spinning after the last card.
3. Drawing. Usually omitted as a separate process.
4. Spinning.

B. Worsted or Combed Yarn.

1. Picking or teazing. For mixing. (This machine is often omitted.)
2. Carding. These machines as in wool (*q.v.*).
3. Preparing gilling.
4. Combing. The result of this process is the top. Dyeing is frequently done in the top, and is called stock dyeing. It is also done in the yarn (skein) and in the piece after weaving.
5. Backwashing.
6. Gilling.
7. Drawing. Many times repeated. The last step before spinning is called roving.
8. Spinning.

Explanation of Processes

Sorting. — Wool usually comes to our market unwashed or "in the grease," and the fleeces must be sorted into their different qualities after they reach the mill. Some wools are scoured and carbonized before shipping to market, in which case the stocks are mixed and are not in the form of a fleece. The manufacturers, in general, prefer the wool "in grease." When the bags full of fleeces arrive at the factory they are opened and the wool is taken to the sorter's tables or benches (Fig. 82).

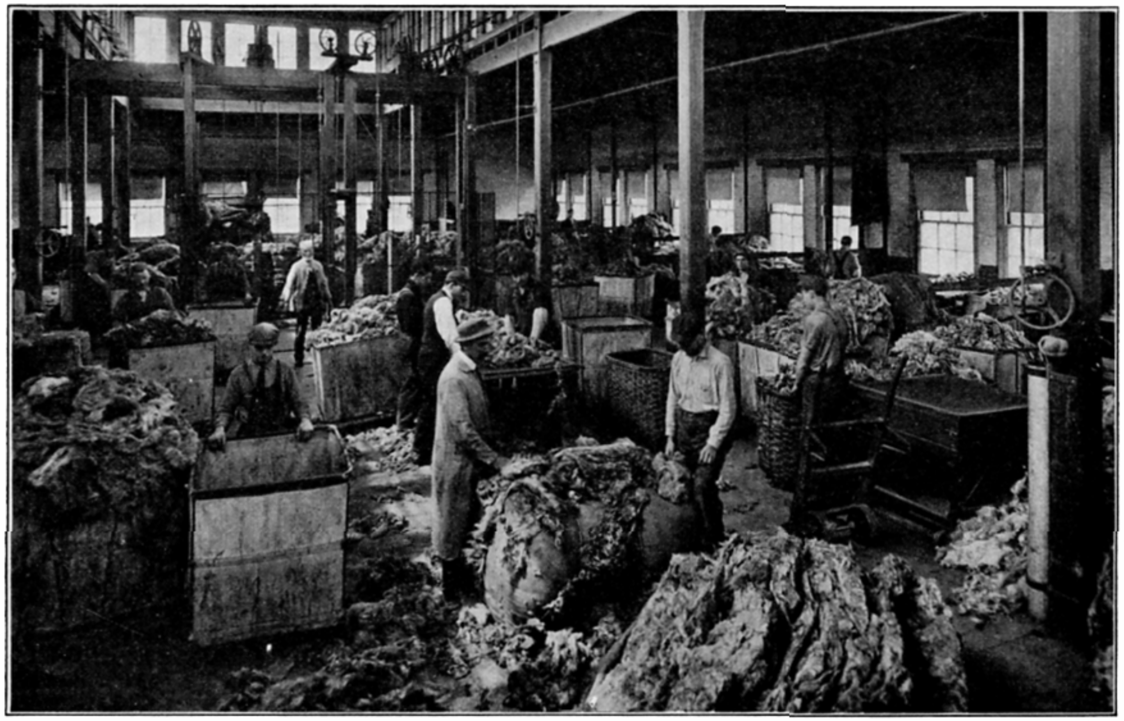

Fig. 82. — Wool Sorting.

Courtesy of M. J. Whittall.

The sorters are trained to recognize accurately the various qualities by look and feel, and quickly divide by hand a fleece into a number of parts, often six, eight, or even more, as occasion demands. The best wool comes from the neck, shoulders, and sides; the poorest, from the legs. The useless parts, which are often full of paint, tar, clay, and filth, are cut off and discarded, and the remaining portions are graded by the sorters. Foreign fleeces come to us with the worst parts removed (skirted); the remaining classes are called sorts. The terms picklock, prime, choice, super, and others are sorters' terms to designate the different qualities for the woolen industry. The same terms are used a little differently in the market. A very fine, short wool is often distinguished in the textile journals by the size yarn it will spin. For example, such terms as 60s, 70s and others indicate fine Saxony or merino wool. The sorters in each mill select the quality or qualities needed in that special industry, and the remainder of the fleece is sold. The fleece as it comes from the sheep may be graded into many qualities, as Fig. 83 indicates, No. 1 being the best grade and No. 14 the poorest. In a general way it may be said that the wool from the shoulders is fine; from the sides, long and even; from around the neck, fine but short; from the back, short and coarse; from the tail and legs, coarse and of little value, and under the body it is short and dirty. A special method of dividing the fleece into sorts is used in some of the mills of the United States. Good wool grows on tender flesh, consequently good mutton and good wool come from the same part of the sheep.

There have been and still are dangers to those who sort wool, especially dusty, Eastern wool. Wool sorters disease, anthrax, comes from a germ which enters the body through a break in the skin or by the internal organs. Many difficulties come from it, the most serious being blood poisoning and inflammation of the lungs. Medical knowledge is increasing as to the prevention of the wool sorters' disease, and modern methods of constructing the sorter's benches have minimized the trouble by placing wire gratings on the top, and exhaust fans below to carry off the dust. Some fleeces are so dirty that they are mechanically opened and beaten before sorting. After separating the wool into its different qualities, the classes are piled in bins marked with their names. Wools from all over the world — white, yellow, black and gray — rest side by side

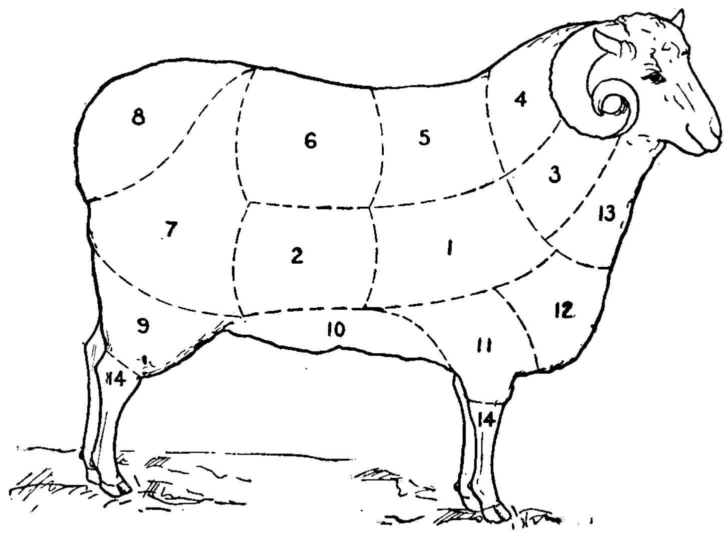

Fig. 83. — Position of Sorts.

From Collins' *Woolen and Worsted Spinning*, by courtesy of the American School of Correspondence.

ready for use. When the wool is needed, it is usually blown through pipes or carried by other automatic means to the part of the mill where it is needed.

The Feed. — (A species of opener.) When wool is very matted and dirty it must be cleaned before scouring. This process is required by short staple wool rather than by long. Wool impurities are difficult to eliminate. Sand and dust can be beaten out, straws and burrs require carbonizing, animal impurities are removed, in general, by washing. As much dirt as possible must be eradicated very early, or the cloth will be injured. In many mills automatic feeds are used before dusting, before scouring, and before carding, as a means of opening the wool and passing it on in better condition to the next process. Feeds are built either high or low, according to the length of wool which is to be passed through them. The wool is deposited in the hopper of the machine, and an apron of spiked slats carries it upward to an oscillating comb, which throws the surplus wool back into the hopper and carries the remainder to a revolving beater. The coarse spikes open the matted fiber, the dust is beaten out and falls below, and the wool is removed from the apron and passes to the next machine. A similar feed is used for cotton (see Fig. 101). In some mills a separate machine opener is found for matted wool, but the increasing practice is to have the feed a part of a train of machines which cleans, washes, and dries the wool.

Dusting. — Wool which is very full of straws, dust, and burrs requires repeated cleaning. The duster consists of a cylinder covered with coarse teeth or spikes, which opens the staple while a fan blows out the dirt. There are two forms of duster, the square and the cone. The work of scouring is simplified by this machine, consequently it is in use even for fairly clean wool. It often follows the feed in the train.

Scouring. — Wool, as already explained, contains a greasy matter, called yolk, which is secreted from the skin of the sheep, and makes scouring necessary. The cloth will be in better condition if as much dirt as possible is cast out beforehand so that the scouring process need not be too severe (Fig. 84). When this process is well done the wool comes out clean, soft, and fluffy, and free from the chemicals which have been used in the cleansing solution. Care must be taken, however, that the wool is not injured, for too hot water (it should not be warmer than the hand can stand) or a too strong alkaline solution will weaken the fiber and consequently the cloth. It is generally

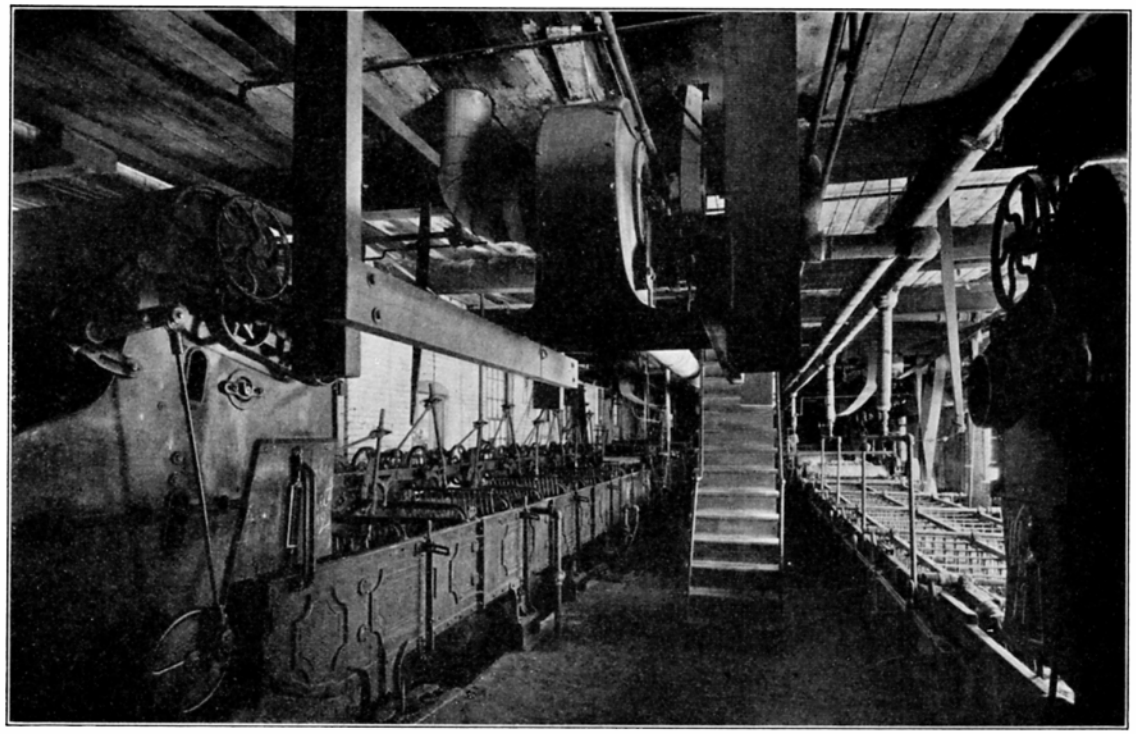

FIG. 84.— WOOL SCOURING.
Courtesy of M. J. Whittall.

conceded that poor washing is followed by defective cloth. Each mill has its own washing formulæ, but potash, ammonium carbonate, and soda are in frequent use. The washer is a long, narrow trough, divided into several tanks or bowls of different sizes, according to the length of the wool used. The first bowls are scourers and are filled with warm, soapy, alkaline water; the last bowls are rinsers. A ducker plate pushes the wool on to the liquid. Fresh water flows in continually, and the soiled water passes out. Wringers are attached to each bowl, and the wool moves slowly toward them, carried along by rakes attached to the sides of the troughs. After each wringer the wool passes in cleaner condition to the next bowl, and in the final one is washed in pure water. It should issue from the last wringer clean, white, and soft, to be carried automatically to the dryer, unless it is to be dyed before drying. Violent treatment of the wool in the scourer leaves it felted, ropy, and stringy. A train of machines such as the Feed, Duster, Scourer, and Dryer can be attended to by one or two men without needing to handle the wool.

A naphtha system of cleaning is used in some mills, and it is claimed to yield excellent results. The wool is placed in a hermetically sealed tank filled with naphtha, which removes the dirt. The expense of this method of scouring has been an obstacle to its general adoption.

The market at times quotes the price of wool on a scoured basis. If a variety of wool in grease costs 25 cents a pound and loses 50 per cent weight in scouring, it will take two pounds of such wool to make one pound of the scoured, hence the price on the scoured basis would be 50 cents a pound. Wools differ greatly in their shrinkage.

The by-products left in the scouring water are of great value, and consequently are recovered and used again, or sold.

Raw Stock Dyeing. — When wool is very burry it is frequently carbonized before stock dyeing, unless the chemicals which are used in carbonizing will affect the wool so that it will not take the color satisfactorily.

Drying. — It is very important for the sake of future processes that the wool shall be evenly dried. A hydro-extractor, similar to the kind used in large laundries, casts out the excess moisture by centrifugal force. The wool is next spread on a series of frames, made of network, placed one above another, and hot air is driven through by a fan; or it is dried in a large drying chest, where it passes for a time over hot air pipes and is then carried to a huge drum, on which it is turned over and fed back to the pipes until it is thoroughly dried.

Blending. — In many mills wool is burred and picked or teased before blending, for drying often entangles the fibers, and they need to be opened. Blending is especially important in the woolen industry, as the combination of color is often the beauty of the finished cloth. The object of blending is, first, to combine wools of various kinds, such as Australian with Ohio, or with other wools of similar staple, or to mix shoddy, mungo, coarse wools, extracts, pulled wool, cotton, or silk noils with pure wool for the purpose of cheapening the cloth; and, second, to combine wools, or remanufactured wools, of different colors, into attractive effects, such as mixing wool dyed blue with white and with black wool to make blue gray, or combining various colored wools for heather mixtures. Blends must often pass through the teaser several times to perfect the combination. It requires ability, experience, and a feeling for harmony of color to mix wools well, and a successful blender has many cherished recipes. Samples of different wools or of colors are tried first on the hand combs until the right combination is reached, and then the percentages of the various wools are weighed carefully and laid in successive layers on the floor of the mill near the picker or teaser.

Oiling. — Wool loses its oil in the scouring process, and must be re-oiled to pass easily through succeeding machines. Oiling often follows blending, being done by hand or sprayed automatically as the wool lies on the floor, or as it passes on an apron to the picker or other machines. An oiler is often attached to the doffer end of the dryer. If cotton is in the blend, it is better to keep the oil from falling directly upon it. Mills differ in the oils they prefer, but olive oil, neatsfoot oil, tallow oil, and other animal oils are in use. The oil must be evenly spread over each fiber. In the manufacture of soft serrated wools into yarns which will be fulled after weaving, the oiling before carding is very necessary, for it preserves the serrations from injury during the passage of the fiber through the thousands of fine teeth.

After oiling or blending, the processes for woolen or worsted yarns begin to diverge. The machines used are often much alike, but, as different results are required from them, modifications in structure are necessary. Worsted raw stock, after oiling, goes directly to the card unless some blending is necessary, but the latter is less important than in the woolen industry. Worsted goods are distinguished by their combed, finely twisted yarn and clear weave, rather than for soft mingled coloring and obscure pattern.

Woolen Yarn

Burr Extracting or Burr Picking. — Short staple wools are often full of burrs which persist in spite of the work of sorters, and of various machines. These must be removed before carding, or they will injure the machinery and be so crushed into the wool that removal is difficult. Mills differ in the manner and time of burring. The elimination of burrs, seeds, and leaves is, however, usually effected by two different systems: (1) A mechanical method which consists of a roller covered with a series of toothed rings which open the wool, and a fluted beater or guard knife to knock out the vegetable matter. A brush strips the cleaned wool from the machine. The mechanical burring is used especially when fine wool is full of large burrs, the advantage of it over the second method being that the natural strength and color of the wool are not affected. (2) A chemical burring is also in use, which carbonizes the vegetable matter. The wool is placed in a bath (usually a sulphuric acid solution) which attacks the burrs but does not affect the wool. A rinsing of soda and water follows, to free the wool from acid, and it is then baked until thoroughly rid of the vegetable matter, which has become carbon. This method is considered to be very effective, and is especially good when the burrs are broken and matted in the wool. Carbonizing is often repeated after the cloth is woven, if vegetable matter is still present. Burring rollers are sometimes attached to the carding engine. In very dirty wools, both burr picking and carbonizing are often used.

Picking, Teasing, Opening, Willowing, and the Fearnaught. — (Names used in different localities for this process.) A picking machine is usually required after scouring and drying, to open the entangled fibers, but it often comes after the blend has been made in order to combine the various wools or other fibers, and to prepare for carding. The picker is much like the carder. In place of the mixing picker a toothed cylinder is often attached to the first card. The blend is placed on a traveling lattice or apron, and carried into the teeth of the cylinder, where it is opened, mixed, made pliable and flexible, and then is automatically passed to the card.

The length of time required to prepare and spin woolen yarn differs. Inexpensive yarns take but a few minutes from sorting to spinning, but the processes may be lengthened, repeated, or supplemented by additional machines when making higher grades of yarn.

Carding. — The carding for woolen yarn is done in a set of three machines, which are much alike except in their methods of doffing the slivers. In America these machines are called the first breaker, second breaker, and third breaker or finisher; a condenser often is connected. In England they are called scribbler, intermediate, and condenser card. The aim of the woolen cards is to open and clean, but not to lay the fibers in parallel order. The first breaker card (Fig. 85) is often preceded

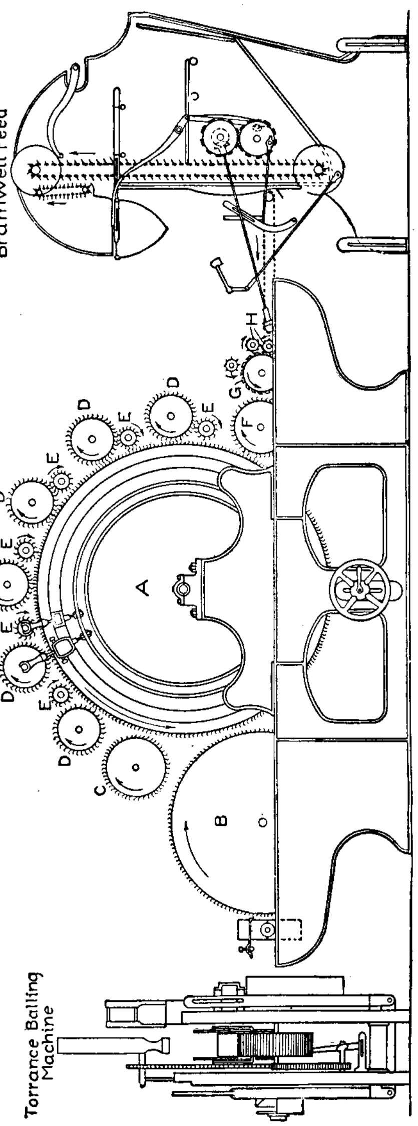

FIG. 85. — FIRST BREAKER CARD.

From Collins' *Woolen and Worsted Spinning*, by courtesy of the American School of Correspondence.

by an automatic feed, which opens and blends the wool, delivers it to a weighing pan, and evenly deposits the correct amount of wool on an apron to be carried to the breaker. Each breaker card consists of a large cylinder against which small cylinders called workers and strippers revolve. Thousands of teeth clothe the surface of the cylinder, becoming finer in each succeeding breaker, and open up the wool. The first card combs the wool into a fine film or sheet, which in that form or in a sliver passes to the second; from the second breaker the film is delivered in various ways, but often is contracted into a wide sliver and fed diagonally (" on the bias ") to an apron by an oscillating feed, which carefully deposits it back and forth, one layer half over and yet alongside of the other. The licker-in of the third breaker receives the wool from the side of the sliver, consequently the tendency to the parallelism of the fibers which has been given by the teeth of the card is counteracted. The product of this third machine is made ready to go to the drawing frames in the manufacture of some classes of yarn, or in others is condensed by a ring doffer and rub rolls into a coarse, lightly twisted roving wound on bobbins, which goes directly to the spinning frame. The heavy edges of the folded-back sliver are separated from the rest of the wool automatically when they issue from the breaker, and are later returned to the hopper of the feed to be carded anew.

Drawing and Doubling. — These machines are similar in all the wool industries, being based on the principle of drawing by rollers. (See Chap. II.)

Mule Spinning. — (See Fig. 22.) The intermittent motion of the mule spinning frame, which adapts it to the twisting of soft, short staple yarns, makes it of service in the woolen industry. The roving, which is soft and slightly twisted, with the wool fibers running in all directions, is placed in the frame, drawn smaller and twisted more, but has still the same characteristics as in earlier processes. The yarn comes from the mule spinning wound on bobbins.

Skein Dyeing or Dyeing in the Yarn. — If the yarn is now to be dyed, it must be wound into skeins or hanks on the swifts, (Fig. 86).

Fancy yarns are made in many ways. Colored yarns are united, threads are looped or knotted and often again twisted with other yarns, fibers of other textiles are combined with the wool, and yarns are twisted in different ways and again twisted together. Woolen yarns are used for knitted and crocheted goods, for blankets, for staple materials such as broadcloths, flannels, golf cloths, cheviots, meltons, kerseys, homespuns, cassimeres, chinchillas, and fancy dress goods, where the weave is soft and indeterminate or obliterated, and the colors are softly blended. Cotton warps are frequently used with wool filling, as in many flannels, blankets, and fancy dress goods.

Worsted Yarn

In making worsted yarn the wool fibers must be combed until they are parallel and flat before the sliver can be twisted into an even, lustrous thread. Many processes are required to do this satisfactorily, several days being sometimes needed for the work, hence worsted yarn is expensive. After the wool is blended (if this is necessary) it is carried on trucks or blown through pipes to the carding room. A feeder (Bramwell) is sometimes used before the first breaker card (Fig. 85). In some wools a burr roller is attached to the first card.

Carding. — Worsted carders (three cylinders are sometimes used as in wool) differ from those used for woolen yarn in several minor ways, such as slower movement on account of the wool staple; the doffing, as the fibers must be kept parallel, and the way of preparing the sliver for the next process. There are several methods by which worsted yarns are made ready for spinning. When very long staple wool is to be spun into lustrous, closely twisted yarn the combing and gilling processes are especially important, and carding is merely preliminary to the others. In such cases the first breaker card alone is used

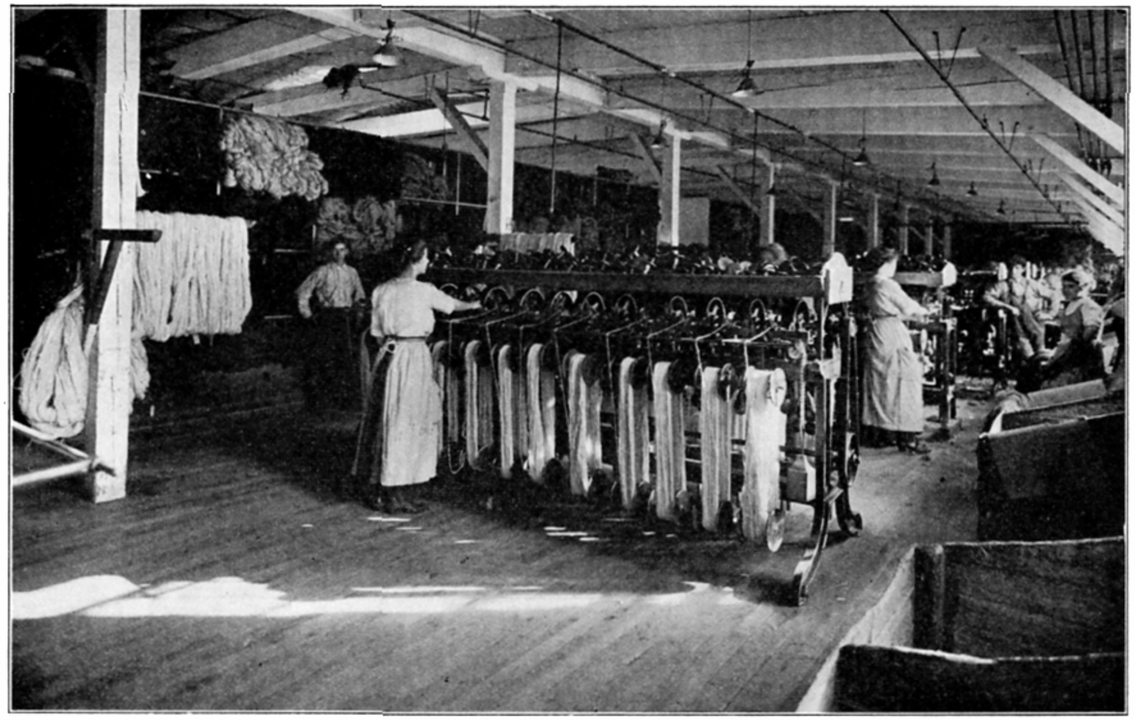

FIG. 86. — WINDING OR SPOOLING YARN.

Courtesy of M. J. Whittall.

(for too much carding breaks the long staple wool), and it is followed by preparers which straighten out the fibers for the comb. When, however, a short staple wool is to be combed for worsted yarn, the carding process becomes important as well as the combing and gilling. In some classes of carpet yarn the worsted carders do the work of opening and straightening the wool, and the combing and gilling are omitted. In general, however, worsted yarn goes through the following steps, but the emphasis on processes may vary: (1) Opening, cleaning, and separating the wool on the feed and the carders; (2) drawing, straightening, and leveling on the preparers (gilling); (3) extracting long fibers from the short, curly ones, and laying the former parallel in the comb; (4) drawing, doubling, and evening the slivers on gill boxes and drawing machines, and (5) drawing and twisting the roving into yarn and winding it on bobbins on the spinning frame.

Back Washing. — The wool becomes much soiled by oil in the carders as well as in other machines and needs washing. The process is used either before or after combing, or even at both times. A back washer is often attached to a preparing gill box. If this cleansing is not done, the cloth is apt to become shiny from the oil left in it. The principle of washing is very simple. Two or four bowls are used for washing and rinsing the wool. Wringers or squeeze rolls follow each bowl to press out the water, and a drying cylinder comes at the end. It is generally conceded that four bowls wash the wool cleaner than two, and that the finished cloth is benefited thereby. The best soap should be used and fresh water should flow constantly into the scouring bowls to keep the soapy solution weak. In place of a hot cylinder to dry the wool, a fan is sometimes used. Oil is sprayed on the wool after back washing.

Preparing Gilling. — A set of five or six preparers often follows the first breaker card, or the three-card cylinders may precede a set of preparers. The aim of these machines is to unite a number of slivers and to draw, straighten, level, and make parallel the fibers to prepare them for the comb. Sometimes as many as twenty-four slivers will be united in a preparing gill box. Gilling is done both before and after the comb, but the term gilling is not used for these machines until after the comb. Preparing and gilling are therefore practically the same process, and the machines are similar in construction. Each gill box has receiving and delivering rollers, between which is a series of bars or fallers covered with teeth or gills. The fallers move on screws from the receiving toward the delivering or draught rollers. As they move forward they press the wool down on a comb and lay the fibers parallel. When they reach the draught rollers they drop below, and are caught on a lower screw and carried back to the receiving rollers, where they are raised to the surface to begin again. The draught rollers move more rapidly than the rollers which are receiving the wool, and consequently attenuate the sliver. The speed is regulated by the size of the yarn desired, or by the length of the wool staple. When the product of the last preparer is to go to the Noble comb a balling head is attached to it, which winds the slivers in such a way that four unwind from one ball and are united in the comb.

Combing. — The slivers which come from the preparers are level and fairly parallel, but short, curly fibers are mixed up with the long ones. The object of the comb is to rid the sliver of the short, curly wool (noils), and to comb the long, straight wool into a more parallel condition, called tops. There are several methods of combing, such as the nip, square motion, and circular combs, but the latter is generally preferred. The nip comb is adapted to English long staple wools, but the Noble circular comb can deal with both long and short staple wools. The aim of the Noble comb is to do the work of the brush and comb, *i.e.*, to make parallel the long hairs and to catch the waste or broken hairs and throw them to one side. In order to accomplish this a series of elaborate and delicate adjustments is necessary. Eighteen balls of the prepared slivers are placed in order around the comb, four slivers coming from each ball. The end of each sliver is passed through a ring in the edge of the circle, and thence into openings which lead to a feed box. Through this they pass to a large, revolving, circular comb, 48 to 60 inches in diameter, where they are caught in the teeth of the combs (Fig. 87). The large circle has several rows of upright, pointed teeth, which become finer as they leave the circumference. Two small circles, 16 to 20 inches in diameter, revolve on opposite sides of the big circle. Rows of teeth decreasing in size are also on the small circles, and they come in contact with the teeth of the large circular comb and lay parallel the fibers of wool with which they come in touch. The longer wool is inclined to remain on the big circle, but the little circles comb it through and take away the short ends, which are called noils. The long hairs soon project free from the big comb, and are taken from it by vertical rollers to make the top, whereas the short ends are carried off in another direction. A dabbing brush presses the wool on the teeth of the combs. The slivers from the balls are carried by the feed boxes on an inclined plane so adjusted that they are at the highest point when they pass the dabbing brush. As the boxes descend the plane the wool is pressed down on the teeth. The fibers which remain between the teeth are automatically lifted out by knives and fed again to the combs. The slivers are kept from slipping back from the feed boxes by nips which hold them. The small circle on the opposite side from the large one combs through the wool which has not been combed by the first one. Both small and large combs revolve together and in the same direction, and rest on a steam chest which aids the combing by keeping the wool warm (Fig. 88). As a result of the combing two slivers come from the large circle and one from each small circle, and are united into one, a false twist being sometimes given to the sliver before it falls into a can. The combed sliver is called a top, and the processes following make it into a finished top.

The noil is removed from the teeth of the small comb by

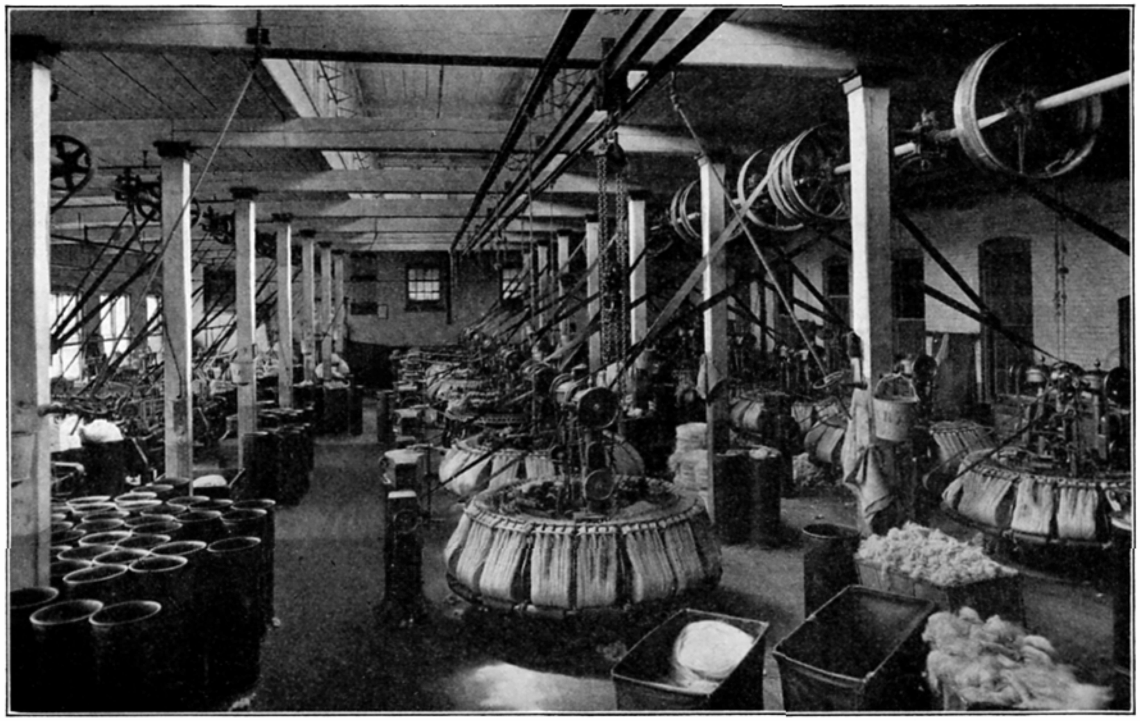

FIG. 87.—WOOL COMBING. THE NOBLE COMB.

Courtesy of M. J. Whittall.

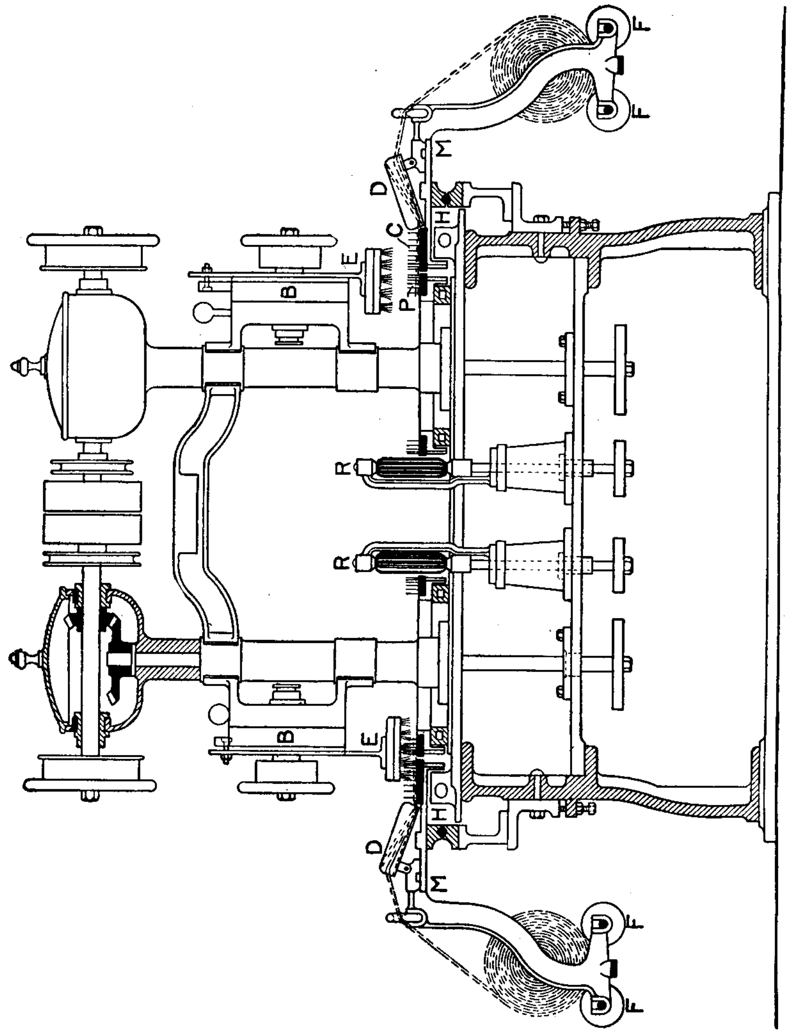

FIG. 88. — DETAIL OF NOBLE COMB.
From Collins' *Woolen and Worsted Spinning*, by courtesy of the American School of Correspondence.

knives and passed to rollers which convey it from the machine. It is used in many ways, being often combined with pure wools for dress goods and blankets. Some mills use their own noils, but frequently they are sold to other manufacturers.

Finishing Gilling. — The aim of the two or more gill boxes which usually follow the comb is to blend more completely different length fibers, to increase the parallelism, to apply moisture evenly to every fiber, and to wind the tops into a ball which will easily unwind. To accomplish this very fine teeth are necessary in these gill boxes. As many as twenty-eight

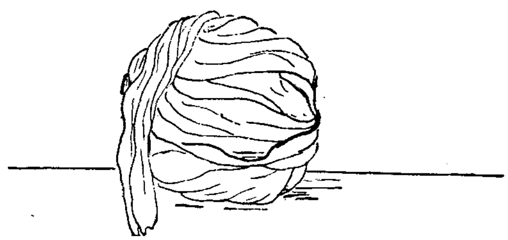

FIG. 89. — TOP.

cans from the combs are at times united in the first finisher gill box, the result of which is a heavy sliver. Three or more slivers are united into one in the last gill box, and by a balling head attachment the finished top (Fig. 89) is wound. In some classes of yarn no real twist has yet been given to the sliver. Many mills buy their tops instead of making them, as it saves expense. Combing and gilling are costly operations, and mills having well-equipped plants frequently do a commission business in tops, returning to the purchaser tops, noils, and waste. Wool sold in this form often has an excess of moisture in it, which increases its weight and consequently its cost to the buyer. To offset this condition, which is sometimes fraudulent, conditioning houses have been organized to test wool. Standards of moisture have been agreed upon, and variations from this affect the sale of the wool. Silk conditioning houses were long ago established in Europe and are now increasing in the United States. They now test both wool and silk for moisture as well as honest condition of the fibers.

Drawing and Doubling. — The tops must now be reduced to a size small enough to spin, as in previous machines a number of slivers are united into one. The drawing process is repeated from six to nine times, until the required size is reached. In some classes of yarn little twist is given until the machine which directly precedes the spinning (the roving), whereas in other varieties the thin yarn is repeatedly twisted. The product from these machines is wound on bobbins. It is stated that worsted yarn is often doubled a half million times before it is ready for the spinning frame.

Spinning. — (Fig. 90). There are two methods of spinning worsted yarns: the Bradford or English system, which thoroughly oils the wool before combing and gives a smooth, lustrous yarn fitted for worsted suitings as its final result; and the French or dry spinning, which uses shorter wool, little oil, and spins a soft, dull yarn. The latter system offers more difficulty in handling the wool on account of the increased electricity arising from the lack of oiling, and it costs more, but it yields a soft, clinging material much in demand. The principal difference between the two methods is in the drawing and spinning, as the former system requires much twisting, and the latter avoids twisting. Soft yarns are spun on the worsted mule, which is almost identical with the mule for woolen spinning, but closely twisted yarns require the throstle or upright frame, by the use of the flyer, cap, or ring principles.

Counts or Sizes of Yarns. — The sizes of yarns are variously indicated in different localities and countries. The United States has two systems in general use for woolen yarns. The first originated in Philadelphia and is called the "cut"; the second is used in other parts of the United States, and is designated as the "run." Both methods are based on the number of hanks or skeins required to make a pound, but differ in the

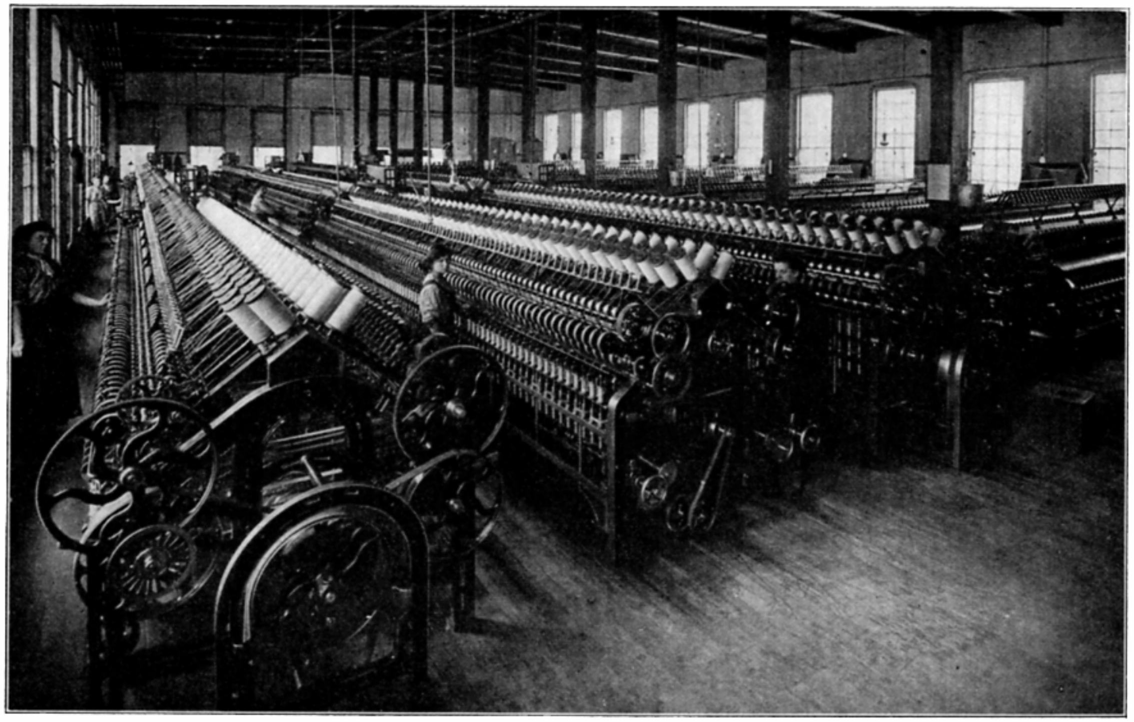

Fig. 90. — Spinning the Wool

Courtesy of M. J. Whittall.

size of the hanks. The " cut " system takes 300 yards of one-cut yarn (the coarsest) to make a pound (one hank). As two-cut yarn is as fine again as one-cut, it will take 600 yards of it to make a pound, which will be in two hanks. In the " cut " system the coarse yarns in general use are five-cut to seven-cut (lower sizes are seldom used); medium yarns are eighteen-cut to twenty-one-cut, and fine yarns are thirty-cut to thirty-five-cut. The market expresses these cuts as 1/30s cut when speaking of single No. 30 yarn (thirty hanks), or 2/30s cut when speaking of two-ply No. 30 yarn.

The " run " system has 1600 yards to the pound for one-run yarn; No. 2 run yarn is twice 1600, or 3200 yards to the pound (being twice as fine as No. 1 run). Fine yarns are estimated in a like manner. In the " run " system Nos. 1 to 3 would be coarse yarns; Nos. 3 1/2 to 5 would be medium, and Nos. 6 to 8 runs would be fine.

The sizes of worsted yarns are estimated by the " count." In this system 560 yards of 1-count yarn weighs one pound, and higher " counts " are estimated as in the " cut " and " run " methods. In worsted yarns Nos. 30 to 40 are comparatively coarse; 40s to 56s are medium yarns, and 60s to 100s are fine; 60s is the standard worsted yarn.

Worsted and combed wool yarns are used for weaving, knitting, and needlework (crewel, Berlin, zephyr, and Saxony). We find worsted yarns in serges of many varieties, diagonals, prunellas, panamas, Venetian cloth, and voiles, and as the filling with cotton warps in alpacas, mohairs, Sicilians, and other luster goods. Yarns from the combed wool industry are found in underwear, fancy dress goods, soft serges, and buntings. They are combined with cotton or with silk in such materials as poplins, henriettas, lansdowns, and challies.

Weaving and Sizing. — Yarn comes from the spinning frames on bobbins, but has still many processes to undergo before it is finally woven. When skein dyeing is necessary the bobbins must be run off into skeins or hanks on the swifts, and after dyeing wound back on bobbins. Filling yarn goes directly to the weave room to be wound for the shuttles. Warp yarns require closer twisting than those for the filling. Some yarn is doubled before being woven, and has to go to a special machine which twists the two yarns in the opposite direction from the previous twisting. Warp yarn is frequently prepared for the loom by winding it on large dresser spools. Forty or more ends come from each spool, and as many spools are required as will make up the number of threads in the warp. Thousands of warp threads are required for ordinary cloth. The spools are placed on a creel and the threads are drawn off on a beam in the order in which they will be needed in the loom. If the yarn is to be sized or slashed, it usually is done at this time. The object of sizing is to strengthen the yarn and keep it from roughing up in the drawing-in and weaving. Inferior yarns are often sized so that they will stand the strain of weaving. Single woolen and worsted yarns are usually sized, but two-ply yarns need it less. Many of the mills of the United States do not size their yarns before weaving, as the extra machinery and time consumed add to the expense. There are many ways of sizing and many ingredients used, such as Irish moss, dextrin, gum arabic, potato starch, cornstarch, glue, and mucilage. The slasher is ordinarily a long trough filled with size, through which the threads from the beam pass. Rollers press in the size and also squeeze out the extra amount, and a heated cylinder dries the yarn. Much of the size drops out in a fine dust during the weaving. The yarn is warped before it is sized, and afterwards is drawn in and reeded before it is woven. (See Chap. IV.) Piece dyeing follows weaving, but the exact time for it depends on the finish the goods must have.

Finishing. — The beauty of woolen goods lies largely in the finish of the cloth; and of worsted goods, in the weave. Both rely on attractive color combinations. Stamped patterns and elaborate Jacquard designs are not used as often as in silk and cotton materials. Many of the favorite weaves are simple, such as the plain or tabby, the basket, stripe, and check. Twills or diagonals, satins, corkscrews, herringbones, ribs, cords, crêpes, and double-faced cloths are also staples. Many effects are gained by the use of yarns twisted in novel ways, by combining other fibers with the wool, and by finishes and dressings applied after the weaving is over. Worsted suitings, when taken from the loom, look much as they will in the finished state, but woolen cloths, especially those which are to be fulled, are far from attractive, being coarse and rough and requiring many processes to develop their beauty. Woolen and worsted cloths may be finished in an infinite number of ways, but certain processes (which follow) may be taken as representative. The same processes are, in general, applied to both kinds of cloth, but when worsteds are fulled it is only to soften the weave, while the object in woolens is often to obliterate it entirely. Fulling can be watched and stopped when desired, but broadcloths and other dress face goods are given the maximum of shrinkage. The latter materials are woven both longer and wider than they will be in their finished state, for they frequently shrink one third in each direction. They are therefore woven as much as eighty inches wide that they may be fifty-two or fifty-four inches when finished. Broadcloth, melton, and kersey are usually woven with a twill which throws the warp on the face, consequently carded wool yarn is used for the warp, for when fulled it will cover the filling. Worsted filling is sometimes used in broadcloth, but the character of the weave throws it to the back. Cloth woven with the plain or tabby weave and fulled is sometimes called broadcloth, but is really a fulled flannel, and is less satisfactory than broadcloth. The present demand for very light weight, pliable broadcloths for women's wear has reduced their strength while increasing their softness, for any defects of stock or early processes combined with the close shearing leave them weak and liable to tear. The finishing of dress face goods changes the rough, coarse product of the loom into the soft, satiny appearance which distinguishes these materials. Good stock and numerous processes make these goods expensive.

Inspection or Perching. — Poor stock, careless scouring and blending, inferior chemicals, and injuries in the many processes show when the goods come to the finishing stage. The most rigid inspection by experts is given the cloth after weaving, after mending, and after finishing. The material is drawn over rods or over an inclined plane and defects are noted, marked with chalk on the cloth, and remedies are suggested. These difficulties sometimes require that the cloth be sent back to previous machines for treatment. If the wool cannot yield good results, surface finishes, artificial stiffenings, lusterings, and dressings are used. Even with good stock carelessness or machines out of order may have caused injuries which must be mended. The material is now weighed and measured.

Burling and Mending. — The usual difficulties with the cloth are unsightly spots caused by knots, bunches of threads, and thick or thin places, which are removed by special tools or by the fingers. This is called burling. Mending is required when the threads have broken or the weave is imperfect, and the design must be woven back exactly. The burlers and menders are generally women who are skilled handworkers and sewers. Worsted suiting requires very careful mending, as the final finish will not cover the defects, as will the fulling for dress face goods.

Washing and Drying. — The cloth is frequently soiled by the machinery, and must be washed before it is finished. Some woolen cloths go to the fulling mill without washing, but worsteds are usually scoured in a special machine in which soap, Fuller's earth, or other cleansing materials are in solution in warm water. Careful rinsing follows the washing, to rid the cloth of oils, glues, and chemicals, as well as of dirt. Moisture is removed by a hydro-extractor, and the cloth dryed in a cloth dryer or by a vacuum process.

Fulling, Milling, Felting, or Shrinking. — This process is a very important one. A large number of cloths are slightly fulled to soften the appearance of the weave, but materials which are thoroughly fulled lose their weave lines, and after further finishing present a soft, even pile which has given them the name of dress face goods. Fulling takes advantage of the property of shrinking which is found in many wools, but especially in those having numerous scales or serrations. Moisture, heat, and pressure or rubbing increase this tendency, for the rough under surfaces of the scales resist interlocking until softened. Woolen yarn felts easily on account of the crisscross arrangement of its fibers. Cloth woven from such yarn and fulled decreases greatly in length and width, while increasing in bulk. A pattern woven in the cloth will be reduced in size. Goods which are to be fulled are not only woven longer and wider in proportion to the shrinking which will occur, but must be woven loosely enough to be soft and pliable after felting, yet close enough to be substantial, for close weaving often results after felting in a boardlike cloth. Fulling strengthens good wool, but poor, tender wool cannot be made strong in this way, though it may have a solid appearance. Cloth which is to be fulled is sewed together in an endless belt, and it is folded with the selvages together and with the face inside. The fulling mill is a sort of huge chest or closet in which warm, oily, soapy water can act upon the cloth while it passes, twisted and hanging in loops over vertical rollers, under heavy hammers or in a trough. The friction also causes heat and aids in the felting. For slight fulling, as is needed in some worsted suitings, a couple of hours will suffice, but for broadcloths and meltons many hours are often required. Woolen cloths are not usually washed before felting, as they are cleaned sufficiently by this process and the washing which follows. Cloth which lacks in weight and density is frequently flocked in the fulling mill.

Flocks. — Finely cut up wool waste can be fulled into cloth, making it firmer. This is usually applied to the under side. Flocks made from good stock, and applied to pure wool cloth, are not a detriment to the finished material. It frequently happens, however, that flocks are used to cover up defects and to deceive the purchaser. The careless choice and preparation of the flocks and the use of them to thicken and give feel to material made of inferior wool, shoddy, mungo, and cotton, give almost worthless material. After a time the flocks drop out and the real poverty of the goods is evident. This short, fuzzy waste can be found frequently in the linings of wool coats and skirts, consequently it has become customary to leave the linings free, thus allowing the waste to fall out unheeded. Mill waste, sweepings, and clippings from the gig and shear are used. Fancy dress goods are sometimes made having as a surface design white or colored flocks which were added to the yarn while being spun. Flock wall papers are made with these same fine clippings, which are blown on the surface.

Washing, Drying, and Tentering. — After fulling, the cloth requires careful washing or rinsing to rid it of soaps. It is then dried in a hydro-extractor and perhaps later in a dryer. If vegetable matter is still present in the cloth, it must be carbonized. Before the cloth is dry enough to be " set " it must go to the tentering machine. In olden times the cloth was fastened between posts in the mill yard, where it dried for several days, but now it is stretched carefully on a long frame, gripped on each selvage and passed over steam coils. This process removes cockles and creases, and sets the cloth evenly across the filling, which is most important, especially if cropping is to follow, for irregularities of surface will be cut. Cloths which show their weaves, if tentered carelessly, have the filling threads running a little on the bias, or the materials lack in smoothness. Cloths which are to be napped are moistened with water to make the next process effective.

Napping, Gigging, or Raising. — These terms are almost interchangeable. Fulled cloth is rough and dull in appearance; the lustrous, soft pile which adds to its beauty and strength is made by roughing up the surface to disentangle the fibers and make them into a thick pile or nap, and then cutting them even with the shear.

Worsted suiting is merely napped enough to make the weave look clean and bright. Brushes are often used instead of teazles. Flannels are napped so that the weave is softened, but such felted goods as broadcloths and meltons have the pile so raised that the weave is completely obliterated. They have to pass many times through the gig to accomplish this. Defects are often concealed by softly raising a surface and finishing it to look well. The Raising Gig (Fig. 91) is a large, open cylinder on which a series of slabs or shallow boxes, the width of the cylinder, may be fastened. The best means of raising the nap is the teazle (Fig. 92), which is a vegetable growth something like a stiff thistle. Fine wire raisers are sometimes used, but have this disadvantage, that they break the cloth when in contact with a knot, whereas the vegetable teazles break first.

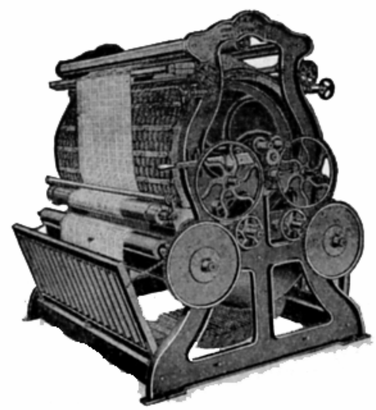

FIG. 91. — DOUBLE-ACTING GIG.
Courtesy of Curtis & Marble.

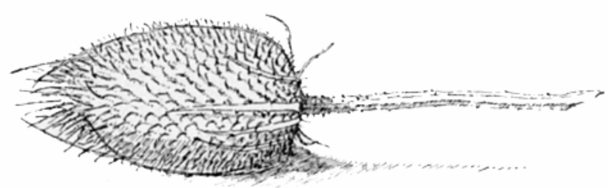

FIG. 92. — TEAZLE.

The narrow troughs or boxes are filled with the teazles laid lengthwise, so that they present a continuous napping surface. The cloth is stretched tight in the machine, a humidifier often sprays it as it passes slowly along, and the napping cylinder moves rapidly in the opposite direction, rubbing up the surface of the material with the teazles. The process is repeated several times, at first with old, soft teazles and gradually with stiff, new ones, until the surface is thoroughly covered with the raised fibers. The nap becomes finer as the gigging is repeated. There are two methods of napping, the wet and the dry. In the former, the cloth is kept moist, and the resulting pile is more

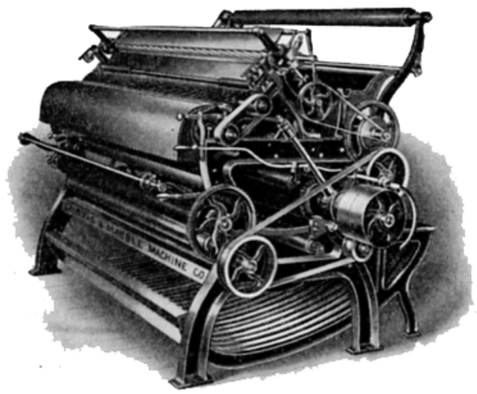

FIG. 93. SINGLE CUTTER SHEAR.
Courtesy of Curtis & Marble.

shiny than in the dry raising. Dress face goods, such as broadcloths, are napped wet. The dry raising is used for worsted suitings and fancy woven goods. The small clippings from the shear are used for flocks or other purposes.

Shearing, Cutting or Cropping, and Brushing. — Cutting the nap and brushing it clean follow gigging or napping. One machine frequently combines all three processes of raising, cropping, and cleaning. The aim of the shear (Fig. 93) is to trim the raised nap to the desired height, it may be merely to even it off, or it may be to cut the nap close. The shear has to be adjusted to the need and requires care, for if the nap is too long the surface roughens with wear; or if too close, the material is weakened.

The cutting surface is a sharp blade arranged spirally around a cylinder which comes in contact with a sharp bar or knife. The two surfaces act as scissors and cut the nap as desired. The principle is similar to the lawn mower. A stiff brush or a set of soft teazles set in a bar follow, and rid the cloth of clippings and dust. Steam brushes are also used for some classes of goods, such as kerseys. After the wet napping and cropping to which dress face goods are subjected, the hand, when laid on the cloth, can move smoothly in the direction in which the fibers have been raised, but feels the opposing nap when moved in the opposite direction. In goods woven entirely of wool the nap is along the warp way. In dry raising, to which worsted suitings and trouserings are subjected, the fiber is lifted to an upright position and the shear cuts it off, leaving the weave distinct. The nap therefore offers no resistance to the hand when passed over it.

The differing order in which the many finishing processes are applied, their repetition or elimination, the appearance and use of new kinds of machines, and the large number of differing cloths, make impossible a definite statement of procedure. Perching or inspection occurs at intervals, and defects are found which must be corrected. Tentering, napping, and cropping are often repeated. Some mills, knowing that irregularities are apt to occur, have these repetitions as a part of their regular schedule.

General Finishes. — Boiling, steaming, pressing, and brushing are all used in varying degrees and times to give a final finish to cloth. Some wools, such as mohairs and alpacas, have a natural gloss which is increased by pressure; other wools can have a permanent luster brought out by treatment, and a surface finish can be applied to poor stock, giving it an attraction which is more or less enduring. Boiling or steaming, sometimes called crabbing, brings out luster, and is employed for some woolen goods and for many worsteds. It is used after tentering with some classes of goods, and after gigging and shearing, or even after pressing, with other kinds. The following are representative methods: (1) wrapping the cloth around a roller and boiling it for several hours; (2) wrapping the cloth around a perforated copper cylinder through which steam is forced, occupying several minutes; (3) placing the roll of cloth in a steam chest. The material in each instance is treated first on one side and then on the other. Cloth which is to be dyed in the piece is frequently sent to the dye house after steaming. It is sewed into an endless belt by uniting the two ends, and is passed through the dye until the requisite color is gained.

Sponging (decating) of cloth after its completion is necessary to keep it from spotting in the rain, as the luster is so fine that small drops of water injure it. All old housekeepers remember the careful sponging and pressing to which they subjected newly purchased cloth before it was made into a suit. The larger dry goods stores will now have the goods sponged before they are sent home. In the manufacture of woolens and worsteds in England and Germany the sponging is now done before it leaves the factory, both for the cut-up trade and the retail. As yet the United States has not made a specialty of this, but some of the largest mills are installing decating apparatus. This part of the business should be attended to at the factory, where it can be done to much better advantage than at home or in the small tailor shop.

Final Pressing. — A preliminary passing of cloth through the calender is often done before inspection occurs. Dress face goods are frequently thus pressed after the shearing and brushing, and are pressed again as a final finish. A calender is a highly polished heated roll on which the cloth is pressed smooth and given luster. Dry steaming often follows to make the gloss permanent, or steaming can be used to reduce an excessive luster. As a final finish a spindle or hydraulic press has been in use for some classes of goods, which gives a glaze to the material, but the calender is taking its place. The method of pressure in the spindle press is as follows: The cloth is carefully folded with press boards between the folds, so that one layer of cloth does not touch another. Hot plates are put above and below, and hydraulic presses or screws bring pressure upon the cloth. It is left over night in the press, and then taken out and refolded in such a way that parts not pressed before now receive an equivalent amount. Pressing adds to the look of solidity in the cloth as well as to the luster.

Brushing of various kinds is also used in the final finishing.

Special Finishes. — Cheviots, which partake of both woolen and worsted characteristics, though in general they are worsted, show the weave, but it is softened by some fulling and raising, and not as clear as in the regular worsted suiting. A good worsted cheviot costs about twice as much as when made of woolen yarn. In the latter case it feels softer and is less liable to wear well. The original cheviots were made from the wool of the English cheviot sheep. Venetians are made of wool, but the weave, which is a sort of upright twill, is definite and clear like a worsted. Thus worsted and wools partake at times of opposite characteristics, from variations in their finish. Flannels woven plain or with a simple twill are finished in many ways. At times they are subjected to the processes of worsteds and clearly show the weave. They are even woven with worsted yarn and dry finished. Still other varieties, such as the opera flannel and ladies' cloth, are woven of woolen yarn and fulled, napped, sheared, and pressed to look like broadcloths. They are sold at different prices, being made of pure wool or in many degrees of combination with cotton. When made of all cotton they can be chemically treated to feel like wool, given the finish to look like wool, and even labelled "all wool." It is sometimes difficult to distinguish differences in materials, even though they bear dissimilar names. Unfinished worsteds, for example, which have the nap left on, look much like cheviots, though the process of finishing has differed. The former, however, are more open in weave, which can be seen when held to the light. The worsted cheviot has a crisper feel in the hand than the unfinished worsted.

Special machines are used to give varieties of surface, the chinchilla machine being illustrative of such mechanical finish. The chinchilla cloth is made with a special weave, and is later fulled, gigged, and sheared to give it a long, soft nap, which is well opened and made erect with a wire brush. The cloth is now placed in the special machine, which has a rotary attachment, and rubs the nap into small rolls, bunches, or points. By adjustment of the machine these bunches can be made to lie in stripes or other designs. When this cloth is made of pure stock good results follow, but frequently it is manufactured of shoddy, cotton, or poor wool, and is unsatisfactory. Cotton warp with a wool filling thrown on the surface is frequently used in its construction.

The true worsted suiting is finished much more simply than the dress face goods. After weaving, it is generally sufficient to wash, tenter, brush or gig (to raise the nap which obscures the weave), crop the surface to make it bright and distinct, and crab and press to give permanent luster.

Fibers are removed from yarn or cloth by several methods besides shearing, such as gassing or singeing, in which the yarn or cloth is passed quickly through a gas flame, which singes it without burning. Scouring or dyeing often follow on account of a slight discoloration. Passing the cloth rapidly over white hot copper rollers also removes the surface fibers. The electric current is also used for napping and cropping as well as for other finishes.

Worsteds are usually dyed in the slub (top) or in the skein (spun yarn). A method of obtaining mixed effects such as the pepper and salt, called Vigoureux printing, has been used in France, and is being introduced into America. (See Chap. XIII.)

The use of surface finishings of innumerable kinds is very general. They are employed to beautify, to strengthen, and to conceal defects. Starches, gums, soaps, and chemicals are the usual dressings. Frequently they are injurious in character, or help to deceive the consumer as to the real nature of the fabric.

The feel of one textile can be given to another by chemical treatment. Cotton is made to resemble wool and wool to have a silky effect. Moiré and embossed designs can be made by special machines, by the use of gums and starches. Crêpon effects and waterproof and fireproof finishes can be given by chemical means. Goods are made absorbent or antiseptic, are made to have a pleasing feel and soft finish, or are given weight and substance as well as gloss and luster, by surface treatment. Many materials which are lightly woven are subsequently stiffened on the back to give them an appearance of body which they do not really possess. Poplins, bengalines, reps, and bedford cords are at times thus made to have a "good body," which is a questionable economy to the consumer, as the size comes out where any rubbing occurs and leaves the sleazy material. When materials are heavily weighted with vegetable matter they will deteriorate unless antiseptics are applied, which are often injurious in themselves, on account of their content, though the manufacturer may have bought them in good faith.

New discoveries in industrial chemistry are resulting in new methods of finishing. The chlorination of wools; printing in light and dark; the production of unshrinkable yarns; combinations in one cloth of felted and unfelted surface, and giving silk effects in the rustle as well as the appearance are interesting methods of gaining diversities in material. Reliable trade journals should be consulted constantly by those who wish to know of new finishes and whether practical results have followed from the experiments which are being tried.

Other Uses of Wool and Worsted Yarns. — *Felt* which is made of serrated wools was not woven originally, but was carded, felted, and pressed into cloth. At present it is frequently woven first, and fulled and finished later. A cheap kind of horse blanket is made which looks like felt, but is constructed in the following way: Sheets or laps of carded wool are placed on both sides of coarse burlap. These layers are made into one piece of cloth by means of thousands of needles, which pull the carded wool back and forth into the burlap, the rough jute or hemp fibers of which hold the wool in place. The finish gives the material an attractive surface. Large quantities of wool and worsted yarn are used for *knitted goods*, for cardigan jackets, sweaters, hosiery, caps, shawls, gloves, mittens, underwear of all kinds, boot, shoe, and glove linings, and classes of materials such as eiderdown flannels, used for wrappers and blankets. In eiderdown flannel the wool is knitted into cotton stockinet and is made both single and double faced. The finishing of this material gives it a soft nap. Cotton is used largely in combination with wool in the knitted goods industry.

Rugs and carpets are made of both woolen and worsted yarns, but the latter give the best wear and are the more expensive. These floor coverings were originally made entirely by hand by tying or twisting short ends of yarn around the warp threads and holding the loops in place by the filling. The loops were cut by hand by means of sharp knives. The machine-made products imitate the hand made, and are frequently constructed on specially adapted looms. The worsted yarn is made from coarse, hairlike wools. The yarn is not only doubled and twisted after spinning but often three of these two-ply strands are twisted into one, and several of these are used in each loop. The best carpets have a hemp or linen back and a well-dyed worsted yarn for the face. In good pile carpets the filling is thrown through the warp three times after each row of loops, which holds them well in place. There are many varieties of these floor coverings on the market, the principal ones being the Ingrain, which is woven like a cloth with two-ply or three-ply yarn. Venetians and Kidderminsters are similar. The weave is sometimes plain, but frequently there are elaborate designs which reverse the color on the front and back. Either side of the carpet can be used. Ingrain carpets with two webs are woven usually on Jacquard looms and are enduring and rather expensive when made of good three-ply yarn, but are made in all qualities and prices. They are manufactured with worsted in both warp and filling, or with worsted warp and wool filling, or with worsted warp and cotton, jute, or even poorer filling. The best quality has a large and definite number of warp and filling threads to the inch, but the poorer qualities reduce the amount and consequently the endurance. Drugget or felt is sometimes strong and serviceable, but often is cheap and poor. It is made plain or with a design printed upon it.

Pile carpets are constructed with the loops uncut, as in Brussels, or cut, as in Wilton. They have two warps. The best carpets have a worsted surface. Wool is used in some varieties. The kind of fiber used for the backing makes considerable difference in the expense of the carpet, and also figures in the wear. Flax, hemp, cotton, cotton waste, and jute are all used according to the price of the carpet. After weaving, pile carpets are finished usually by brushing and shearing. Brussels carpets are made in several qualities, depending on the stock used, the number of threads in a loop, the loops in a given space, the class of dye used in the yarn, and the material used in the backing. The number of colors possible in a design is limited, as the yarn for each color must be dyed separately. Brussels carpets are woven on a special Jacquard loom, in which the worsted yarns for the surface loops are wound on spools and placed on large frames at the back and slanting towards the loom. Each color is on a separate frame, and there are about two hundred and fifty spools on one frame. The warp which is used for the backing is either wound on spools also and placed on the lowest frame, or it is wound on a beam and set at the back of the loom in front of the frames. The backing threads, both warp and filling, are also dyed. A body Brussels, which is considered the best kind, takes its worsted yarn into its very foundation, so that the colored worsteds show on the wrong side of the carpet in the midst of the backing threads. If it is a five-frame Brussels it will have five colors on the frames, and when one of these colors appears on the surface of the carpet the others can be seen at the back. There are several threads in each loop. The filling usually is shot across twice in Brussels, for the loops are less apt to pull out than if they were cut, in which case a three-shot filling is better. Flax and hemp make the best backing for both warp and filling, but cotton is sometimes used satisfactorily. Well-made Brussels carpets are very enduring and also expensive. The loops on the surface are made by passing the worsted yarn from the frame over a series of wires and holding down the loops thus made by the filling threads. The rods or wires, usually eight or ten in number, come automatically in place, and are each withdrawn and placed at the end of the row after the filling holds the row of loops on the surface.

Tapestry Brussels carpet is a poor imitation of the real Brussels. Many colors are used in it. The design is made first on squared paper, the scheme of color in each pick of the pattern is studied out, and the succession of it sent to the printer. The skeins of yarn to be used for the loops on the surface of the carpet are wound on a large cylinder, attached to which are troughs of color which come in contact automatically with the yarn, and print it according to the succession of colors indicated in the design. The skeins are taken from the cylinder, showing crosswise streaks of varied color, and are carried to the steam chest to have the dye set. When the carpet is woven the pattern is complete, but has a less distinct outline than the real Brussels. The Jacquard harness and the frames full of bobbins are not needed, hence expense is spared. A simple harness is used, and wires are required to make the loops. The rows of loops are usually farther apart, and often but one thread is used in each loop. The backing is generally jute or some inexpensive fiber, and the face is a poor quality of worsted yarn. Flecks of color are often printed on the back to increase the resemblance to body Brussels carpet, and thus deceive the consumer. Tapestry carpet which has the loops cut is sometimes called velvet carpet.

The original Wilton rugs were, and are still, made by hand in England on upright looms. They are of great beauty and worth, and are high in price. The machine-made Wilton is a copy of these, and an excellent article, at a much lower price. It is woven like a Brussels carpet, but has the loops cut, for the wires over which the loops are made have sharp edges which cut through the worsted threads as they are drawn out from the row just made. The Wilton carpet is usually woven of better worsted and backing yarn, a greater number of fibers are in each loop, the loops are closer together, and the filling thread, which binds the loops together, passes across three times after each row of loops is made. The warp frequently requires as many as two thousand threads. The number of colors for a design in Wilton carpet is limited as it is in Brussels. The French Moquette carpet is similar to the Wilton, and also named from the town of its manufacture.

Axminster carpet is a pile carpet resembling the Wilton, but numerous colors are possible by a special arrangement for the supply of worsted yarn. The design is made, and the colored yarn as needed for each line of loops is wound on a separate small cylinder. These are placed in an endless chain above the loom, and the threads from each are passed through a series of slots or needles. Each cylinder drops in place when needed, and makes its row of loops. It then automatically passes up to wait until it is again needed in a repeat of the pattern. Royal Axminster carpets are expensive. In England Axminster carpets are sometimes called Moquette, but the latter is more like Wilton carpet. The terms velvet and Moquette have been used rather loosely in America for cut pile carpets. Chenille Axminster carpets were so called from the tufted cord of which the loops were made. A special loom was invented to weave a variety of cloth and then cut it into narrow strips along the warp, which formed the chenille cord. This cord is woven into the surface of the carpet. The principle is much used for the manufacture of chenille curtains. Glasgow has manufactured chenille carpets; the United States does not import them to any extent.

Wastes and By-products. — The large variety and value of wastes can be seen by referring to any textile journal, and noting the kinds of products under such headings as Rags new and old, Shoddy, Machine Waste, and the like. An efficiently run factory takes the pounds of machine waste and its disposal into account when estimating the cost of its product, as well as the expense of the raw material, labor, repairs, equipment, and overhead expenses. The final cost is reduced by selling wastes, noils, or clippings, and the effect is felt in the market price of cloth or of clothing. Mutton, pelts, leather, rugs, cloaks, and oils help to make the utilization of the sheep one of the greatest industries in the world.

Countries Manufacturing. — The leading manufacturing countries are: (1) Great Britain, to which we look especially for worsted suitings and diagonals. Leeds is a noted center, Preston and Manchester are well known for the special finish they give their goods, Bristol and Bath make dress goods and trouserings, and southern Scotland is looked to for tweeds. (2) France excels in fine woolens and combed wool dress goods. (3) Germany has many large manufacturing towns noted for woolens and worsteds. (4) The United States does a large business but exports little. Thirty states have woolen and worsted mills. Philadelphia is the leading city; and the principal manufacturing states, in the present order of their volume of business, are Pennsylvania, Massachusetts, Rhode Island, and New York.

Cutting-up Trade. — The great increase of ready-to-wear clothing for men, women, and children has caused a demand on the manufacturer for classes of goods made especially for the "cutting-up trade," as it is called. Some mills are working solely to supply these large clothing houses, and sections of trade journals are devoted to these interests.

WOOL AND WORSTED MATERIALS

	Width	Price
Albatross	36–45 in.	\$.50–1.00
Albert cloth	54 in.	3.00–5.00
Basket cloth	42–54 in.	1.00–2.50
Beaver	54 in.	3.00–12.00
Bedford cord	50–54 in.	1.00–2.50
Blankets		7.00–29.00 pr.
Brilliantine	42–54 in.	.50–2.00
Broadcloth	50–54 in.	1.25–4.00
Carpets		1.00 up
Cashmere	42–44 in.	.75–1.50
Cassimere	54 in.	3.00
Challies	30 in.	.50– .75
Cheviot	42–48 in.	.75–3.00
Chiffon cloth	54 in.	1.75
Corkscrew worsted	45–54 in.	1.00–2.50
Covert	52–54 in.	1.00–5.00
Cravenette	50–56 in.	1.50–3.50
Crêpe cloth	42–45 in.	1.25–1.50
Crêpon	44 in.	1.25–1.50
Diagonal	45–54 in.	1.00 up
Etamine	42 in.	1.25–3.00
Felt	24–50 in.	.80–1.50
Flannel	27–36 in.	.55–1.00
Frieze	54 in.	2.00–5.00
Gloria	36 in.	1.00–1.50
Golf cloth	54 in.	1.25 up
Granite cloth	42–45 in.	1.00–1.25
Grenadine	42 in.	1.00–2.00
Henrietta	38–45 in.	1.00–1.50
Homespun	42–50 in.	1.00–3.00
Hopsacking	54 in.	1.75–2.00
Kersey	54 in.	2.00–5.00
Ladies' cloth	44–54 in.	1.00–4.00
Marquisette	36 in.	1.50–3.50
Melton	52 in.	2.00–4.00
Mohair	40–54 in.	.75–2.00
Nun's veiling	36 in.	.50–1.50
Panama	42–54 in.	1.00–1.85
Polo cloth	54 in.	2.50–5.00
Prunella	42–45 in.	1.00–1.50
Ratine	54 in.	1.75–3.00

WOOL AND WORSTED MATERIALS — *Continued*

	Width	Price
Serge	42–54 in.	$1.25–2.75
Shepherd's plaid	46–54 in.	1.25–2.50
Suiting	42–58 in.	1.00–3.50
Tweed	52–54 in.	2.00–4.00
Venetian	54 in.	1.00–2.50
Voile	42–45 in.	1.25–2.00
Whipcord	54 in.	.75–1.50
Zibeline	42–54 in.	1.50–4.00

MIXTURES WITH WOOL

	Width	Price
Alpaca	36–45 in.	$.25–1.00
Astrakan	36 in.	4.00–18.00
Bedford cord	46 in.	2.25
Brilliantine	44 in.	.50–1.50
Eolienne	42 in.	1.50
Henrietta	45 in.	1.00–2.00
Lansdowne	40 in.	1.25
Marquisette	36 in.	1.50–3.50
Mohair	40–54 in.	.75–2.00
Sicilian	42–54 in.	.50–2.00

CHAPTER VII

THE COTTON INDUSTRY

Economic and Commercial Conditions. — The vegetable fiber cotton is of more value to mankind than any one of the other textile fibers, on account of its cheapness, its availability, and its varied usefulness. The materials made from it range from the finest threads, mulls, and laces, to heavy blankets and sailcloths. Its value is enhanced by its resemblance, after special treatment, to linen, wool, or silk, by which warmth and attractive appearance can be gained at a small cost. It is probable that no other plant is so closely connected with the cost of living.

The invention of the saw gin by Eli Whitney in 1792 was one of the factors in revolutionizing the industrial condition of the world, and in substituting the problems of factory production for those of the home. His invention made the cotton of the United States available to the English spinners, and the demand for cotton cloth gave the special impetus to the inventions of Hargreaves, Arkwright, and Crompton. The influence of cotton on the commercial, political, and social relations of the United States is of noteworthy importance. Other countries are depending on us for it, and it may properly be said to make for peace between us and other nations.

Properties. — The properties of cotton which are especially noteworthy are the following: —

1. The fiber has a natural twist (see Chap. XI) which aids in the spinning of it into fine and coarse yarns. When long, fine staple cotton is used and the thread well spun it makes a strong yarn.

2. Cotton burns easily on account of the natural oil in it and its cellulose nature; it is said to be even subject to spontaneous

FIG. 94. — A MODERN WEAVE ROOM, SHOWING AN ACRE OF LOOMS.

Courtesy of the Chicopee Manufacturing Company.

combustion. When cotton is nitrated, it is highly inflammable and is used for gun cotton. Treatment with nitric acid gives cotton more or less a feel of wool, but as it makes it burn more readily than before, there is danger if the material is brought near the fire. Many of these materials are napped to give them still more the effect of wool, and the danger of fire is further increased by the greater amount of air between the fibers.

3. Cotton is very free from impurities, and bleaching cleanses it still more. It can be stored for a long time without deterioration, unless sizings and starches and certain dyes are present. If kept clean it is a hygienic material for wearing next to the body.

4. The hygroscopic quality is less than that of wool or silk. Artificial moisture is needed in its spinning to produce good results. It absorbs water slowly, and does not give it up quickly, consequently it remains damp a long time. To render cotton absorbent, the cotton wax is removed. It does not dye readily unless it is made more absorbent or a chemical is applied for which both it and the dye have an affinity. This mordant, as it is called, holds the dye to the cotton. (See Chap. XIII.)

5. Moist cotton is stronger than dry cotton. When cotton is heated, as under a very hot iron, its strength is less. Alternate moisture and heat do not hurt cotton unless the heat is too great.

6. Cotton crushes and creases easily, and needs frequent pressing. The surface of napped goods and blankets easily flattens down and takes on a rough, shabby look unless often brushed and shaken.

7. Cotton soils readily on account of the numerous fine hairs protruding from the yarn. When it is new and has the sizing or finish still upon it, it will stay clean longer, for the fibers are held down.

8. Cotton shrinks in water and in certain chemicals. This is a natural property, but is augmented in weaving. The strain on the warp threads in the loom stretches the yarn to its full length, and the sizings and starches hold it there. Warm water and soap in the laundry loosen the finish and the yarn contracts.

The shrinking must be taken into consideration when cutting out and making garments. When cotton yarn is put into a bath of a certain strength alkali it will shrink and become stronger and heavier, and will take on a parchment-like appearance. (See Mercerization, Chap. XII.)

9. Cotton is a better conductor of heat than wool or silk, consequently when thin it is a satisfactory summer garment.

10. The elasticity of cotton is less than either silk or wool, therefore the thread breaks more readily when subjected to pressure.

11. The tensile strength is fair. The cotton fiber is stronger than the wool fiber. India Surat cotton is the strongest, and the Sea Island has the least strength.

12. Specific Gravity. This quality differs in various textile fibers, but it is least in boiled-off silk. Wool is lighter than raw silk, and mohair is the same as the latter. Linen and cotton are the heaviest. Cotton blankets and quilts are much heavier than those made of wool of the same consistency.

Botany and Growth. — Cotton consists of the hairs (plumose fibers) which protect the seeds of the plant. It is called a surface fiber to distinguish it from the bast or stem fibers, such as flax or Kentucky hemp. The stalks of the cotton contain bast fiber not utilized at present on account of the expense of preparation. Cotton is almost pure cellulose. While growing, the fiber is cylindrical in form, but as it dries it twists and when fully ripe is like a narrow twisted ribbon (see Fig. 128). This characteristic gives strength when the fibers are made into yarn. Cotton is often short in staple, but a fiber of even three fourths of an inch in length can be spun into a strong yarn.

The cotton plant (Fig. 96) may be an annual, biennial, or perennial. In the United States it is an annual which grows to the height of from four to six feet. In South America and India a more tree-like cotton grows. The leaf of the plant often varies in shape on different parts of the stem. The flower has five whitish or yellowish petals, which are almost saffron color at the

FIG. 95.—COTTON FIELD, SHOWING PICKER AT WORK.
Courtesy of U. S. Department of Agriculture.

base. They last a day, becoming purplish in color, and drop off, leaving a three- or five-celled pod, which increases in size and finally bursts into sections, disclosing the cotton fiber covering the seeds. Some varieties of seeds are covered with a soft surface down called linters, which adheres very closely. This is removed by a second ginning, and forms a valuable crop. Sea Island cotton has shiny black seeds from which the lint is easily taken. Cotton ripens differently, and a plant may contain at one time mature cotton bursting out, together with developing bolls, flowers, and opening buds. A cotton field in bloom is a beautiful sight.

Cotton belongs to the order *Malvaceæ*, or mallow, which also gives the hollyhock and marshmallow. The important genus of the mallow family is the *Gossypium*, which is found varying in height from two to thirty feet. The species are very numerous, for the plant develops new characteristics according to its habitat, the methods of cultivation, choice of seed, soil, climate, and position near or away from the sea. There are many agricultural varieties which have obscured the botanical species. Authorities differ greatly in classifying the species of cotton, but the following are fairly well established: —

Gossypium barbadense, which takes its name from the Barbadoes, where it grows. Sea Island and the Gallini Egyptian cotton come from this species, and the Peruvian is probably more or less related. The kidney cotton of Brazil is a Peruvian variety, the name kidney being given on account of the seed arrangement in the capsule. Peruvian cotton has a long, strong staple which spins to medium fine counts, 45s to 70s. The *Gossypium religiosum* of India is also considered by many to be a variety of the *barbadense*. The seeds of this species are black and free of down. The plants are both annual and perennial, the first growing to three or four feet in height and the latter to six or eight. The *barbadense* grows better in salt air and soil; the fiber is long and silky, and the natural twists are frequent. The yield is perhaps less than the short staple cotton, but the

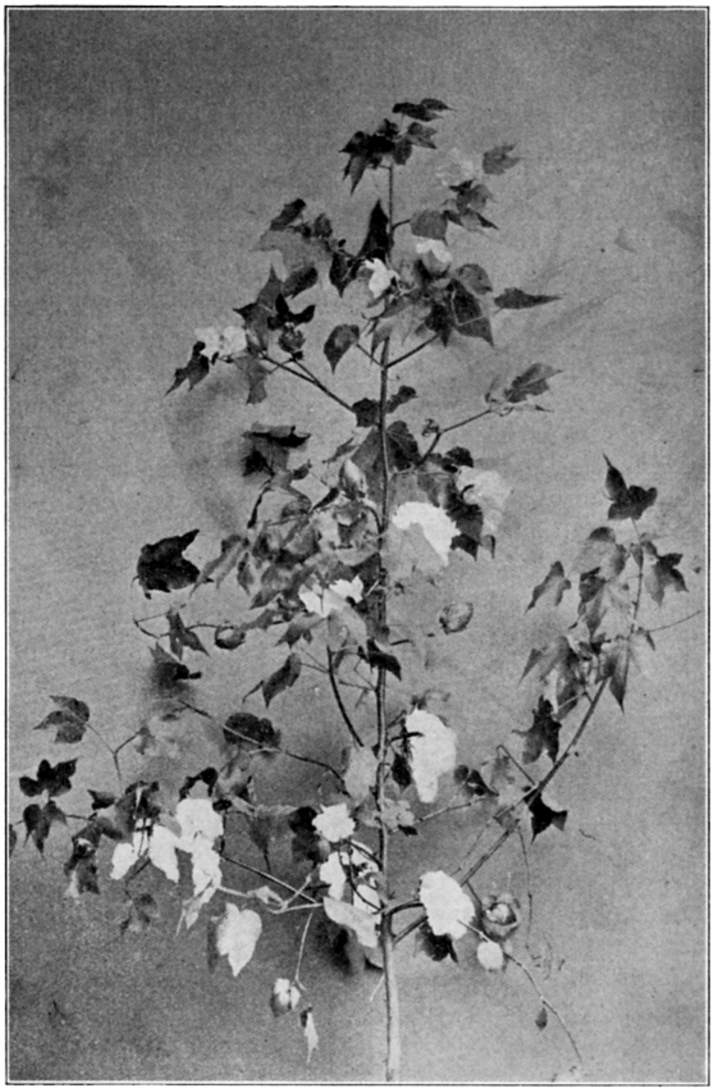

FIG. 96. — THE COTTON PLANT.

From Brooks' *Cotton*, by courtesy of the American School of Correspondence.

value is greater. The highest counts of yarn are spun from it; 120s to 240s. The roller gin is generally used to separate the lint from the seed.

Gossypium herbaceum. — This species is probably of Indian or Asiatic origin, and is both annual and biennial. The Brown Egyptian is from this species, and the Surat of India, which is short in staple, is said by some to belong to it also. The Nankeen cotton of China is a color variation of the *herbaceum.* The seeds are covered with two kinds of fibers: long and silky, and short and dense. The seed cotton has to be removed very carefully, as the hairs adhere tightly to the seeds, and the down and part of the covering of the seeds are apt to come off at the same time. The South American cotton, such as the Santos, Caera, and Pernams, are sometimes ascribed to the *barbadense* and at others to the *herbaceum* or the *hirsutum.*

Gossypium hirsutum is probably of American origin. It is grown as an annual. The name *hirsutum* is given on account of the appearance of the seed, which is covered with a grayish or greenish down. The American medium length cotton staple, such as the Upland, comes from this species. Some experts consider *hirsutum* and *herbaceum* to be the same species. The lint spins to warp threads 34s to 46s, and to filling from 36s to 54s. It is usually cleaned by the saw gin.

Gossypium arboreum and *neglectum.* — These species are much alike, and have the seeds covered with down. They are natives of India, and grow to fifteen or twenty feet in height. They give the Bengal and Dacca cottons of India, and the China cottons. The *Gossypium religiosum* is thought by some to be the same as the *Gossypium arboreum.*

Cotton is cultivated to about forty degrees both north and south of the Equator, but grows best within thirty-five degrees either way. More than half the cotton is cultivated in temperate latitudes. It thrives in a warm, humid atmosphere, with ample rainfall, and a light, loamy or sandy soil which keeps damp yet holds the heat. In a moist, even climate with warm summers, and with salt in the air and in the soil it reaches its highest quality, as in the Sea Island cotton grown on the land near the sea or on the islands off the coast of North Carolina, Georgia, and Florida. Rain in the spring when the crop is growing helps the development of stem and leaf, but heavy rains in the summer when it is maturing injure the production of the bolls. Humidity in the air is better than irrigation, although cotton thrives well under a system of irrigation in Egypt. The plant is very sensitive to frost. The conditions in the southern part of the United States are very favorable, especially the gradual rise of temperature during the entire growth. The great heat in Brazil makes the cotton rough and coarse. Egypt with its warm, bright climate, good water supply, and system of irrigation, is an excellent place for growing cotton, but the area of growth is at present too small for large crops. India has excessive heat, and a want of sunshine during the monsoon summer, consequently the cotton is immature and short in staple.

Outside of the American crop, the leading cotton countries are Egypt, India, South America, Russia, and China. Egypt gives two main varieties, the long staple brown, and a white or rough cotton. The long staple cottons are in great demand in manufacturing countries for the making of strong warp yarns, for the backing of heavy material such as pile goods, for sewing cotton and fine knitted goods. Egyptian cotton is next in value to the Sea Island cotton of the United States. The brownish color of much of the Egyptian cotton is caused by the red coloring matter in the Nile, which stains while it nourishes the plant. It is found classed in three grades in the market. Egyptian cotton is much used in the United States, 121,212 bales of 715 lbs. being imported in 1912 for purposes for which this cotton is better suited than the American. India cotton is grown under adverse circumstances, and therefore is short and coarse. The United States uses little of it, but it is exported to Japan, and to Germany and other parts of Europe.

English spinners find it too coarse for most purposes, although it is used. It is adapted for poorer qualities of warp and filling threads. Brazilian cotton is rough, harsh, and strong. It is classed in three grades, and is imported into the United States to combine with wool, which it closely resembles. In 1912 28,315 bales of 185 lbs. were imported. Both Russia and China grow large quantities of cotton, but the crop is principally used in home consumption, and full statistics regarding it are lacking. About 200,000 bales of cotton are exported annually from China to Japan.

Planting and Picking. — In the southern part of the United States, cotton is planted from March until May, according to the locality. Machine planters are in general use. Methods of cultivation are improving, resulting in a better crop condition, and a better yield. It frequently happens, however, that an unexpected frost or a long wet season will ruin an entire planting and it must be repeated. Even after the growth is well started there are other dangers. Diseases of various kinds attack the plant, and insect enemies are greatly dreaded, for they injure the growth and even ruin the entire crop. Many farmers rely entirely on the cotton crop, for it finds a ready sale even before it is out of the ground, consequently the failure of it means disaster, and anxious hours attend its development.

The crop begins to mature in late July, and it continues to do so until frost, in November or even December. The moment the cotton matures and the open boll displays its seed cotton fully ripe, the picking must begin. It is usually conducted in three stages, in the order of the developing bolls. These open first on the lower branches. The lower and middle bolls contain the best cotton. The gathering is usually done by hand, men, women, and children being at work in the fields from early morning until late at night. A machine harvester would be an advantage if one could be invented able to discriminate between ripe and unripe cotton, leaves and pieces of bolls, and for which the price would not be prohibitive. Machines have been invented which seem almost human, but as yet nothing has been generally adopted for this purpose. The human picker takes hold of the ripe cotton inside of the open boll, and it easily comes off clean. An average picker can gather from 200 to 250 pounds of seed cotton in a day; twice as much, it is said, can be picked by unusually quick workers. Pictures sometimes show the cotton pickers with baskets, but at present they more commonly use long sacks slung over the shoulder and trailing after the picker as he goes along on padded knees. The average pay for gathering 100 pounds of seed cotton is forty to fifty cents. The cost of picking the crop is a large item, especially in low-priced cotton. Careless work is only too common, and affects the cleanness of the fiber. The seed cotton is taken to the nearest gin house, where it is delivered to the gins, usually through suction pipes.

Cotton Ginning. — After cotton is gathered the seeds must be removed. There are two kinds of gins in general use for this purpose, the Saw Gin (Fig. 9), which was Eli Whitney's invention in 1793, and the Roller Gin, which is probably the descendant of the Churka Gin of India. Eli Whitney, a Northern man, was teaching in a cotton district of the South. He saw that cleaning cotton was a laborious task, and that a method of facilitating the work was needed. His machine consisted of a drum with wire hooks or teeth, which rotated against a grate, on the other side of which was the seed cotton. The teeth caught the fiber and drew it through the bars, leaving the seeds to drop to the ground, and a brush took the cotton from the drum. The modern saw gin is an improvement on the Whitney gin. Where two men before Whitney's time could clean two pounds a day by hand, at the present time two men can remove the cotton from the wagon, attend six gins and clean twenty-four thousand pounds a day; *i.e.*, each saw gin cleans at least four thousand pounds a day. The modern gin has a series of circular saws, forty or eighty on a shaft, which project through a slotted plate. The seed cotton is received at *A* and carried against the picker roll *C* and the saws *E*. The seeds drop below and the brush *J* carries the lint cotton to a flue to be carried to the condenser. A single gin may be used, or a number may

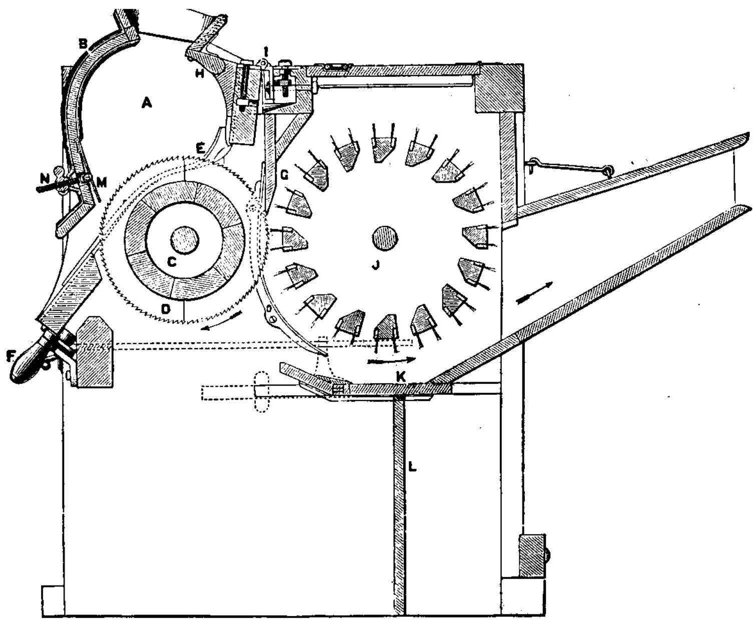

FIG. 97.—THE SAW GIN.
From Brooks' *Cotton*, by courtesy of the American School of Correspondence.

be combined, called a battery. One flue may be used for all the gins, or there may be one for each. The cotton is somewhat cleaned and straightened as it passes through the flue. A 60-saw gin revolving at 60 revolutions per minute will gin about 5000 pounds a day. The saw gin is suited to short-stapled cotton. The fibers of the lint after ginning are crisscross, entangled, and often full of specks and dirt. Several machines must follow in order to lay the cotton in parallel order and clean it.

Saw gins tear and snarl the cotton, consequently many advocate the slower method of the Roller Gin, although it adds to the expense. Gins which do less damage yet work rapidly are needed, and a combing gin has been brought out which claims to clean as much cotton per day as the saw gin without its injury and waste, and to leave it in better condition for spinning.

The Roller Gin is principally used for cleaning Sea Island and long staple cottons. The cotton is fed to a hopper, which has rollers at the bottom covered with rough walrus leather which seize the fiber. A fixed " doctor " knife presses against a roller and draws the fiber between the roller and the knife. The seeds, drawn to the point where the knife touches the roller, are gently but swiftly pushed off by two blades which strike the cotton alternately. The lint is carried on by the rollers and swept off by brushes. A recent roller gin cleans about two bales a day, or about a thousand pounds.

The seeds, which are covered with down or linters, are ginned and are then sent to the oil presses, which are frequently installed in the gin houses.

Baling. — The baling of American cotton follows the condenser after ginning. The method of reducing the bulk of the cotton is by a screw, steam, or hydraulic power, according to the equipment used. A covering of jute is fastened by steel bands around the contracted mass. The bales from the farms generally are not tightly packed, and will not stand long transportation, consequently the railroad and steamship companies have compresses which give a special baling before shipping. The Morse Lever Press is in general use. The cotton is delivered to a special receptacle and a sudden pressure of terrific force (5,000,000 lbs. to the bale) acts on the entire mass, thereby reducing it to a fraction of its original height. The covering and steel bands are fastened about it before the pressure is removed. The elasticity of the cotton and the air compressed in it cause the bale to spring to the turtleback shape characteristic of American bales. The size is usually for uncompressed cotton 56″ high, 28″ wide, and 48″ deep. The compressed cotton bale is approximately 56″ high, 24″ wide, and 32″ deep. These figures are obtained from actual measurement of a number of bales. The weight is about 500 lbs. The tare (covering, bands, etc.) is at least 25 or 30 lbs. Foreign buyers are allowed 6 per cent off the price for the tare, but additional weight is often added wrongfully. The poor and easily deteriorated jute covering gives way with the strain of hauling the heavy bale around with great hooks; the buyers tear cotton from the bale to test it; the cotton is subject to fire, and it is soiled and often weighty with water. The statement is made in a Report of the Department of Agriculture that our cotton bale is "the clumsiest, dirtiest, most expensive, and most wasteful package in which cotton, or in fact any commodity of like value, is anywhere put up. It has no friends among manufacturers, buyers, shippers, insurers, or producers. Custom seems alone responsible for this incubus on the industry." (Bulletin No. 33, *The Cotton Plant.*) The bales of cotton from other countries (Fig. 98) reach their destination in much better condition. The Egyptian bale (700 lbs.) is long, smoothly covered, and easily packed in the ships, so that the cost of carrying is reduced and the loss from dirt and bursting bales is much less. The India bale weighs 392 lbs., being smaller and of greater density than the American bale. The bale for Sea Island cotton is less tightly packed, and weighs 400 lbs. The American Cotton Company has invented a bale, compressed in the cylindrical form by the Bessonette press, which offers many advantages, but for various reasons it has not been popular and is little used.

The Industry in the United States. — The United States produces the bulk of the cotton used in the world (Fig. 99). The actual growth of cotton in this country during 1911 and marketed between Sept. 1, 1911, and Aug. 30, 1912, was about 16,000,000 bales of 500 lbs. The entire world crop was estimated as equivalent to 22,297,000 bales.

The importations of foreign cottons into the United States in

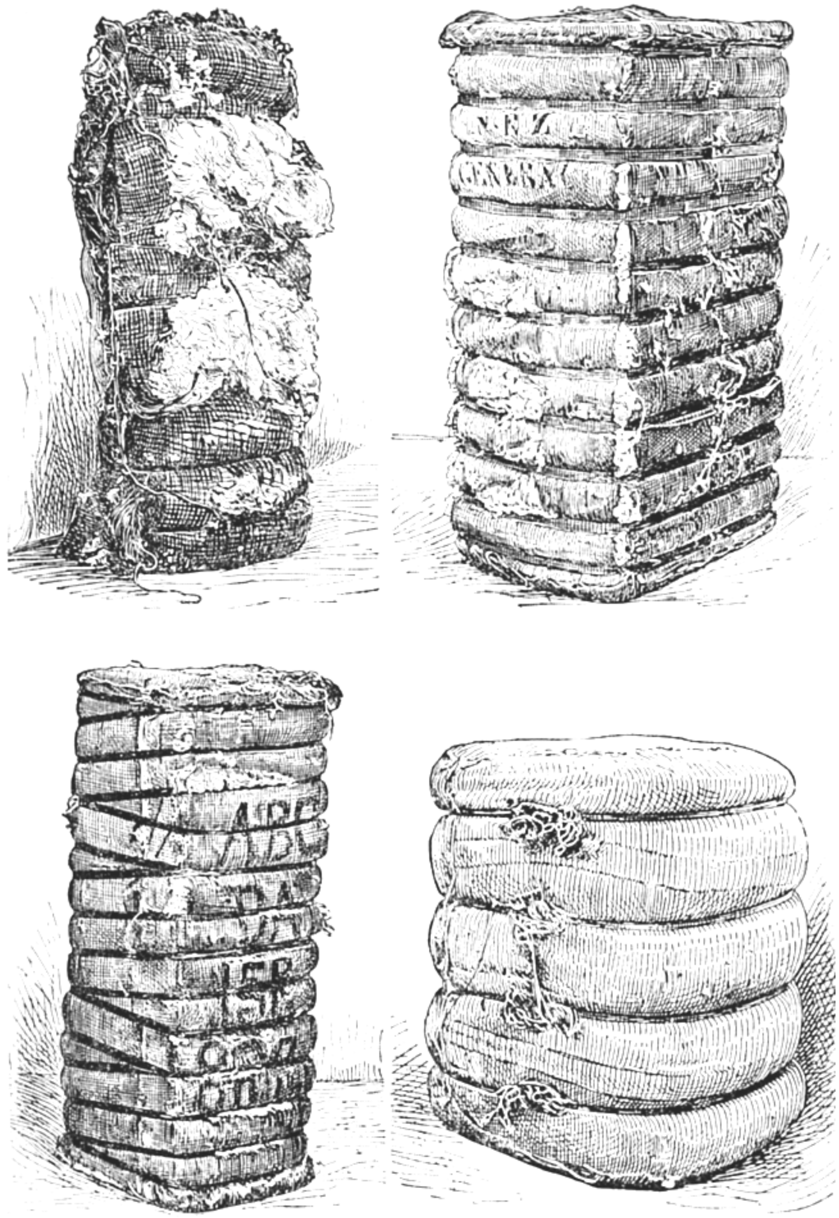

Fig. 98. — Cotton Bales. American bale in upper left-hand corner.
U. S. Dept. of Agriculture, Bul. 33.

1911–1912 were 121,212 bales of 715 lbs. each of Egyptian cotton, and 28,315 bales of 185 lbs. each of Rough Peruvian cotton. These cottons are purchased for special purposes for which American cottons are not suited, and do not therefore compete to any extent with our cotton. As can be seen, the importations of cotton are a small consideration.

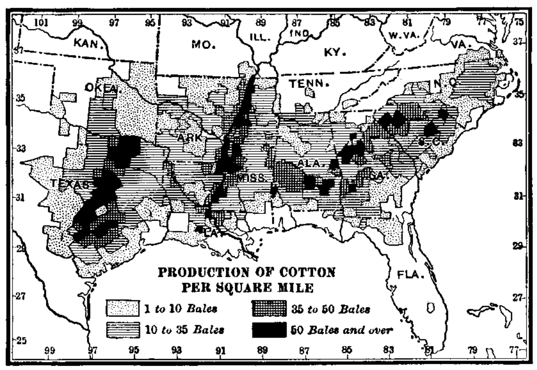

FIG. 99.—COTTON PRODUCING STATES.
From Tarr & McMurry's *New Geographies*, Second Book, 1910, by courtesy of the Macmillan Company.

The American crop in 1912–1913 is estimated at 13,820,000 bales of 500 lbs., exclusive of linters. At an average price of $12\frac{1}{2}$ cts. per pound the value will be $855,920,000. It is estimated unofficially that the linter crop for the same period will amount to 491,300 bales. About two thirds of the crop is exported, but increasing domestic manufacturing interests tend to limit the export. In most of the Southern States cotton is the chief agricultural industry, more than thirty-four million acres being under cultivation in 1911–1912. It is also becoming an important manufacturing industry in many of these states as well.

Cotton in the United States is divided into two great branches, American and Sea Island. The term American cotton covers numerous agricultural varieties which are roughly classed as (1) cotton of the Atlantic States, or upland cotton, which is short in staple; (2) gulf cotton, a longer staple grown on the low lands of the states near the Gulf of Mexico; and (3) peeler cotton, a general term for good cotton grown in the states along the Mississippi River. Another classification which

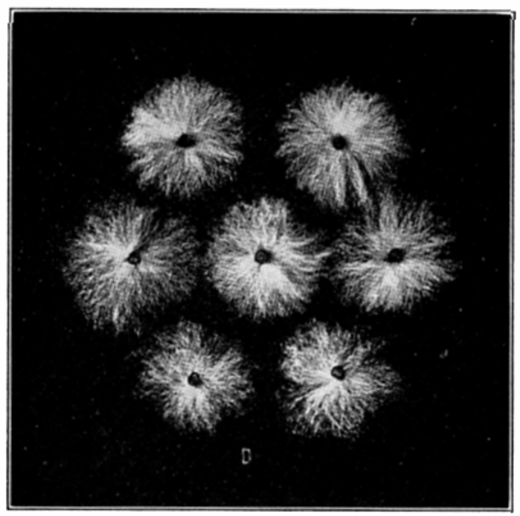

FIG. 100. — COTTON ON THE SEED.

From Brooks' *Cotton*, by courtesy of the American School of Correspondence.

is virtually the same is (1) cotton grown on the uplands of the Southern States with a staple of $\frac{7}{8}$ to one inch; (2) cotton grown on swamp and bottom lands with a staple of $1\frac{1}{8}$ to $1\frac{1}{4}$ inches, and (3) extra or fancy cotton with a staple of $1\frac{3}{8}$ to $1\frac{5}{8}$ inches. The short staple cottons are principally used for filling yarns, the long staple are used for fine yarns, and the extra and fancy cottons for thread, velveteens, and when mixed with Brown Egyptian for hosiery yarns.

Sea Island cotton is the most valuable in the world, being noted for its length and silky appearance. It is grown on rather a limited area on the low, flat islands or coast lands of Georgia, South Carolina, and Florida, and to some extent in the West Indies. A very beautiful variety is grown in the Barbadoes and sells at about fifty cents per pound, but the crop is all taken by a thread manufacturer. Sea Island cotton is used for the finest yarns, from 120s to even 400s; for fine mousselines, laces, mixtures with silk, and for a good quality of sewing thread. It ranges in price from seventeen to twenty-four cents per pound. Egyptian cotton, which most resembles it, sells far below it. In 1911–1912 the crop was 122,766 bales, of which 96,057 were consumed at home, 19,398 went to Great Britain, and the rest to the Continent.

Classification. — American cottons are graded under set terms which carry special prices, based on the condition of standard middling upland cotton. Grades above or below this are measured by the condition of the standard; *i.e.*, the price of standard middling is the basis; better grades are listed as fractions above this, and the poorer as fractions below. The price is determined by a committee of experts of the New York Cotton Exchange, who know the state of the crop and trade. Contracts for cotton to be filled in the future may supply the demand a little above or below the grade mentioned, as crop conditions are uncertain. American cotton in 1912 is found under six full grades. Half grades are shown by the prefix "strict." Quarter grades are indicated by the prefixes "fully" or "barely," as Fully Good Middling and Barely Good Middling. In trade journals the quotations are sometimes under initials which indicate the grades, such as F. for Fair, and S. M. for Strict Middling. There is a tendency as cotton changes in condition from season to season to add new terms for the highest and lowest grades. The words "tinged" or "stained" indicate color variations. The term "linters" is used for the short fibers taken from the seeds by delinting in a second ginning. Low grade unbleached cloth, batting, coarse yarns, and carpet linings in which the clinging pieces of seeds are of no detriment, and artificial silk are made from the linters.

The principal cotton shipping ports of the United States in the South are New Orleans, Galveston, Memphis, Norfolk, Charleston, Wilmington, Savannah, Mobile, and Pensacola. The cottons that are sent from these ports are frequently called by the names of the shipping places, although the contents of the bales may differ greatly in condition. New York City ships a large number of bales to foreign countries.

By-products and Wastes. — During the past half century the by-products of cotton have assumed a large place in the financial world. At one time the seeds were thrown away after the ginning, but they are now used to advantage. In 1912 there were approximately 235,038,000 lbs. of linters alone. The by-products are: First, the linters or the down, which is left on the seeds after the seed cotton is removed. This is removed and used for poor grades of cotton cloth. Second, the seeds, which are pressed by special machinery and yield cottonseed oil, which is now largely used as a food and also has important industrial applications. The meal which remains is used for cattle food. The hulls give bran, fiber out of which high grade paper may be made, fuel, and fertilizers. In the spinning mills there is much cotton waste from the machines, which is sold to be used for cheaper grades of material, for cleaning machinery, or for other purposes. The rags left from used-up cotton garments are sold principally for the making of paper.

Judging and Testing. — The important qualities of cotton are length of staple, strength, fineness, smoothness, uniformity, color, cleanliness, and pliability. The cottons of different countries vary in these qualities, and consequently are adapted to the manufacture of different kinds of cloth. American cotton in general is noted for its whiteness, cleanliness, and regularity of staple. Sea Island cotton from the United States is noted for its length and silkiness, closely resembling spun silk. New

Orleans cotton is renowned for its extreme regularity of staple, which does not vary a fraction of an inch. Cotton manufacturers and buyers know the qualities of the different cottons, though temporary climatic conditions and methods of cultivation sometimes cause changes. Each season the cotton buyers must test the crop to select what they need. The cotton is generally in bales from which pieces are extracted with a hook. The buyer considers (1) the general look and feel of the cotton and whether it is clean (a few pieces of leaf do not matter, but if it is full of sand it is almost valueless for spinning); (2) strength and resistance are tested by pulling the fibers apart between the fingers and thumbs, and by a sudden jerk on the fibers; (3) length of staple and uniformity of growth are estimated by laying several groups of fibers on the dark coat sleeve and noting their appearance. The term "spot" cotton indicates that the cotton can be chosen by the buyer himself, usually in some large cotton market or in some port. The tendency is to decrease these annual sales at some intermediate market for more direct contact of producer and consumer, which will save cost.

Many bales of cotton are partly burned on account of inflammability. Sales of such injured cotton are attended by buyers who bid at a lowered price.

Complaints of the American crop are incessant, and many of them are well justified. The faults should be corrected, if we wish to keep our hold on the world's market. Defective ginning causes the fibers to knot, which will later interfere with smooth spinning, for the knots persist, and show as dense white spots in the web as it comes from the carding engine, and finally as irregularities in the finished yarn. These knots are called neps. The content of a bale is likely to vary greatly in value, as cottons of different length staple may have been ginned and baled together. This condition is trying to the spinner, for it makes uneven yarn. An excess of moisture is frequently found in the bales, which increases the weight.

Cotton may vary in moisture from $7\frac{1}{2}$ to $12\frac{1}{2}$ per cent. If it is above $10\frac{1}{2}$ per cent it is not considered normal, and a rebate of price is demanded. There is also complaint of the amount of tare found in some bales. Foreign buyers are allowed 6 per cent off the price (30 pounds off a 500-pound bale) for bagging, iron bands, etc., but when opened the bales are sometimes found to contain foreign matter which unduly increases the weight. If the buyer accepts the thirty pounds off, he may find when he opens the bale that there is much more tare in it than he was allowed. If he insists on having the cover taken off and the bale weighed before purchasing, he has to bear an added expense, and may find it unnecessary. Foreign lands complain that our 500-pound bales are too big and unwieldy, that our system of baling injures the fiber, that the jute covering of our bales easily deteriorates, that when they arrive in foreign countries they are in worse condition than the bales of any other country in the world, and that the cotton is often mildewed or burned. Our Manufacturers' Association protests against these conditions and claims that it is entirely possible to gin and bale better and with profit to us in the end.

Cotton Spinning has long been an important industry in New England and in recent years has grown rapidly in the South. The Southern mills in 1911–1912 consumed more cotton than did the mills of the North. The preparatory processes of cotton spinning differ according to the fineness of the yarn desired. Early steps are repeated when greater cleanliness is needed and for higher counts of yarn; machines are repeated or even new ones are introduced. The general aim in cotton spinning may be said to be (1) to clean by opening, beating, and fanning; (2) to lay the fibers parallel by carding or even combing; (3) to unite and draw out the fibers, and (4) to twist them into yarn. The constant tension on the fiber, and the millions of teeth which pass through it, reduce its strength. When cotton is poorly picked, ginned, or baled, it requires repeated cleaning to prepare it for spinning, hence it may be greatly weakened. When the preparatory processes have been carefully conducted, the number of machines may be reduced. There is also more waste when cotton has to pass through many mechanical processes, which adds to the expense of the cloth. Cotton is spun best in a humid atmosphere. The Southern States have a damper climate than the Northern, but the climate in America is less satisfactory for spinning than that of England. Humidifiers are used in good spinning mills.

The following processes of cotton spinning and manufacture are representative: —

Bale Opening. Cutting the metal bands and allowing the cotton to expand from its great pressure.

Bale Breaking or Cotton Pulling. A machine which opens up and mixes the staples of various cottons of the same length is used in some mills. The process, however, is still done by hand.

Picking, Opening, Willowing, and Scutching. (These terms are all used for similar processes.) The feed, the breaker picker, the intermediate picker, and the finisher picker of American mills cover the processes of cleaning and opening previous to carding. The result of the pickers is a wide lap wound into a roll.

Carding and often double carding of fine yarn may be required. The results of these machines are slivers.

Combing, used only in preparing the finest yarns. A sliver lap machine is required, if combing follows carding. The result of combing is a sliver.

Drawing, — usually three or more machines. The result is a small sliver.

Slubbing, by a bobbin and fly frame. A slight twist is now required in the product to give strength as the sliver has become attenuated. It is wound on a bobbin to be delivered to the next machine.

Intermediate Slubbing, by a bobbin and fly frame. The result is a twisted sliver wound on a bobbin for the roving frame.

Roving by bobbin and fly frame. A final slubbing when the soft rove is prepared for spinning. It is wound on a bobbin.

Spinning. The frame and mule are both in use, but the former is found more frequently.

Doubling and Twisting. The yarns are prepared in various ways.

Bleaching, Dyeing, Mercerizing, and Gassing of the yarn. These processes are used as necessary. The yarn may be dyed in skeins or warps.

Winding, Spooling, and Warping preparatory to weaving.

Sizing or Slashing to prepare the yarn to bear the strain of weaving.
Drawing-in to thread up the loom.
Weaving.
Finishing as needed, the principal methods being: pressing and glazing, starching and calendering, napping, bleaching, beetling, printing.

These processes are given in more detail below: —

The Bale Breaker or Cotton Puller is much like the wool picker. Cotton from different bales is carried on traveling lattices to the breaker, and is loosened up by means of four pairs of coarsely spiked rollers or beaters, each pair of which revolves more rapidly than those before it. It is thus prepared for the feed of the openers or pickers.

Picker, Opener, Willower, and Scutcher. — In India cotton was originally opened by beating with willow wands to open up the staple. The mechanical means of doing this was called willowing. The term "scutching," which means beating, was used in England for a more advanced willowing corresponding to the work of the intermediate picker and finisher picker of the American mills. The picker room of the usual cotton mill contains a number of trains of pickers, the object of each being to open out the cotton that the sand, neps, leaves, and dust may be eliminated, and to form the lint into an increasingly even and filmy lap. The first machine in the train is an automatic hopper feed (Fig. 101) which connects with the breaker picker (sometimes called cotton opener). The machine is similar to

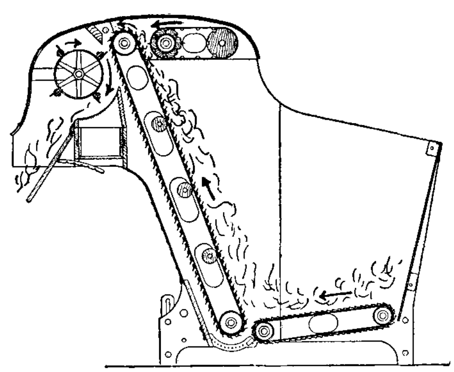

FIG. 101. — SECTIONAL VIEW OF FEED.
Courtesy of the Kitson Machine Shop.

the Bramwell feed. Steel pins on an endless apron open the cotton, which is stripped off by a doffer and carried by an apron to the breaker picker.

Breaker Picker; Intermediate Picker; Finisher Picker. — The object and method of these machines are similar. The cotton fiber becomes cleaner, softer, and more parallel. The film is finally rolled into a wide lap to be taken to the carder. In the first or breaker picker the cotton is beaten by spikes or knives, and driven against cleaning bars or a grate where the dust falls out. The cleaned cotton is carried by a fan to a cage (a cylinder filled with small holes through which the air rushes), and the soft fiber clings to the outer surface of the cage to be carried by guide rollers to the second machine or intermediate picker. Four laps of cotton from the breaker picker are united. The intermediate picker has two or three blades with rather sharp edges which strike the cotton about two thousand or more times a minute. The cotton is then thrown on cleaning bars and carried to a cage as in the first picker. The sheet of cotton thus made is pressed between rollers into a lap wound on bars. In England these two pickers are often called a double opener. A finisher picker, similar to the scutcher of the English mills, is often used, in which about four rolls from the intermediate picker are united, the rolls being laid on an apron and unfolding over one another (Fig. 102). The cotton is beaten by a two- or three-bladed beater as in the intermediate and made into a lap for the carder. Attached to these machines are special parts to even the lap and measure the amount of cotton. The best classes of cotton are sometimes clean enough to require fewer than three pickers.

Carding (see Fig. 19). — This is a very important process. The aim is to clean and lay parallel the fibers. The wide lap from the previous machine is placed at the back of the card and fed to the great cylinder by the licker-in. The revolving flat card is in use for cotton, and closely resembles the wool card (see Fig. 85), but has narrow flat bars filled with teeth fastened in an endless chain over the big cylinder in place of the small

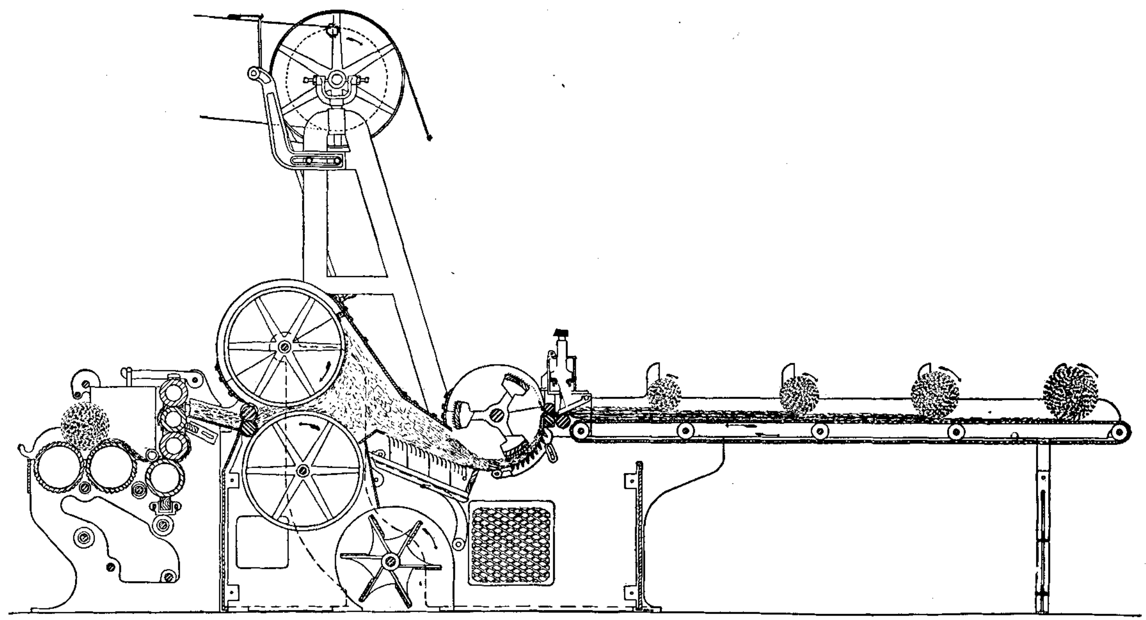

Fig. 102.—Sectional View of Finisher.
Courtesy of the Kitson Machine Shop.

worker and stripper cylinders of the wool card. The flats press the cotton on the teeth of the big cylinder and take out the neps and poor fiber, the action being like a comb pressing against a wire brush. The teeth of the flats are set in an opposite direction to the teeth of the cylinder. After the cotton is carded by the flats, it is passed to the doffer, but the waste cotton is brushed off in another direction. A cotton cylinder has often 700 or 800 teeth on one square inch. The large cylinder may have from four to six million teeth, and the speed is sometimes 2000 feet per minute. The strain on the fiber can perhaps be appreciated. A great deal of dirt is taken from the cotton in carding, and falls into a receptacle below. The thin veil of cotton is taken off the cylinder by the doffer, reduced to a narrow sliver by being passed through an eye or between rollers, or by a method of leather divisions in the apron, and then drops coiled into a can. For fine yarn the carding process is repeated, such yarns being designated as "double carded." The waste cotton from the card is used for many purposes, and special carders are now on the market which prepare yarn from it to be used for inferior grades of cloth. A lap winder prepares the card waste to pass through its own special carder.

Combing. — Cotton is combed when a very fine grade of yarn is needed. It is employed usually for long staple fibers, such as Sea Island, Florida, long stapled American, and Egyptian. This yarn is used for sewing threads, fine knitted underwear, mousselines, and silk substitutes. Short stapled cottons can also be combed by the newer combing machines. The machine follows carding or double carding. Slivers from the card are first united on the sliver lap machine and made into a lap to be fed to the comber. The machine extracts short ends of cotton and impurities, selects fibers of even length and lays them parallel and overlapping, and finally forms a sliver. The method of combing is intermittent, and is accomplished by a nip holding a bunch of fibers, while cylinders covered with card clothing — the needles gradually becoming finer — comb them out first from one end and then from the other. The newly combed fiber is then lapped over that previously combed, and the united fibers are combed again by a suspended comb and finally attenuated into a sliver (Fig. 103). The result is a

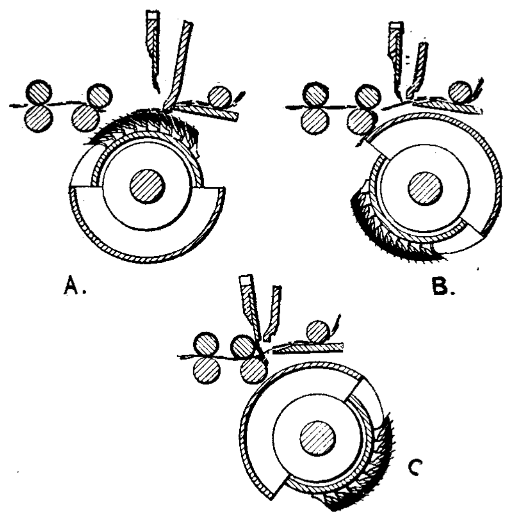

FIG. 103.—DETAIL OF COMBING MACHINE, SHOWING NIP HOLDING THE SLIVER AGAINST THE COMB.

very silky product. The short, rough ends are conducted out of the machine. Naturally there is a great deal of waste from the comber, consequently the process is expensive and is only used with high-priced yarns.

Drawing and Doubling. — This process is usually repeated three times. The aim is to unite several slivers, draw them together, thus removing weak points, and make an even, smooth sliver. The principle is by drawing rollers. The doubling in these and succeeding machines often runs as high for average cotton manufacture as 27,000 to 500,000 doublings, and even goes considerably higher for special yarns. From four to eight cans of slivers are united and drawn together by rollers in each of the three machines (Fig. 104). The slivers are greatly reduced in size and would break unless twist were now given to them.

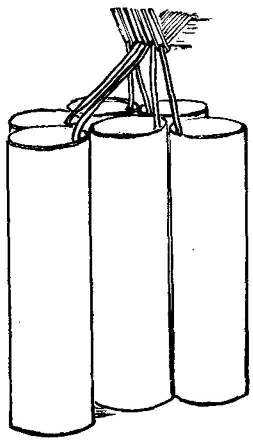

Fig. 104. — Slivers.

Slubbing by Bobbin and Fly Frames. — The first twist is now put into the yarn, and it is wound on bobbins. Two attenuated slivers or soft yarns are united into one in each machine. Slubbing is done by three machines — slubbing, intermediate slubbing, and roving. The methods are the same in each. The result of each machine's work is a finer and more twisted yarn. The final frame makes the roving which is the last step before spinning.

Spinning. — The spinning of cotton is done on the upright frame by the flyer or ring system, or by the mule. The first is a more rapid method and is in more frequent use, but the mule makes a softer and more attractive yarn. Frames with a new variety of spindle requiring almost no attention are appearing on the market, whereby the output of yarn is increased and the cost of production lowered. All modern machines have automatic attachments which stop the action if a sliver or a thread breaks.

Cotton Yarns are spun or twisted in various ways, and are used for warp or filling, knitting yarn, sewing thread, or for hand embroidery. The numbers run from No. 4 coarse even as high as No. 400 for fine yarns. After the yarn is spun on the frame or mule it is usually doubled and twisted before it is ready for service. There are many ways of doing this, and the yarn may be dry twisted or twisted in water. Cotton yarns for weaving may be single or several ply, and the direction of the twist lends variety. Knitting yarns have special twists. They may be spun on the mule, doubled and twisted slightly, with a resulting soft appearance and woolly feel as used in some classes of underwear; or they may be closely twisted in water, dyed, gassed or singed, glazed, and hard finished for lisle thread effects. Sewing cotton is frequently spun on the mule. For three cord sewing cotton, three yarns from the spinning frame are doubled and twisted. For six cord the yarn from the frame is doubled and twisted and three of these are united and twisted. The yarn is sized before being twisted in both cases. When a good grade of cotton has been used a strong thread is the result. Sewing cotton requires more twisting than yarn for weaving, for greater strength is needed. The numbers in sewing cotton run from 6 or 8 to 200 or more. Sea Island and fine long staple American cotton are used in the best grades. All sewing cotton is glazed, but special varieties to be used for the sewing machine have more dressing than those for hand sewing. The spools containing 250 or 500 yards are wound by machine.

Yarn which has been carded, double combed, and then spun on the mule has a lofty, soft appearance like spun silk, but the expense is much higher than when less preparation is required. Special treatment of cotton yarn with gums of various kinds and a later machine polishing between rollers gives the appearance of a linen thread. The cotton thread made in this way is strong but not pliable. Another way of preparing cotton thread to look like linen is by spinning it with small knots or rough places upon it. When the cloth for this yarn is woven and the fabric is finished it closely resembles material which is woven of flax.

Bleaching. — Cotton yarn becomes yellowish in color during the preparatory processes and spinning, and usually requires bleaching. For this purpose it is wound from the bobbins into hanks, which are slipped one inside the other into a chain containing perhaps five hundred pounds of yarn. Bleaching is done in various ways. (See Chap. XIII.)

Mercerizing. — Mercerized cotton is described in Chapter XII. Schreinerized cotton, because of its high luster, resembles mercerized material. The effect is produced by passing the cloth under engraved calenders, with pressure.

Dyeing (see Chap. XIII). — Cotton is usually dyed in the yarn. Dyeing in the unspun state, as in wool, is occasionally used, but this is the exception.

Sizing. — The shortness of staple and the softness of the cotton fiber make it necessary to apply sizing to the yarn that it may stand the strain of weaving. The sizing material is a starchy or glutinous liquid applied to the thread in varying proportions according to need. Sizing of cotton thread has been in use since before the dawn of history. Each modern cotton mill has its own special formulæ. The process, which is generally called slashing, is done after warping and before drawing-in. It is especially necessary for warp yarns. Special sizes or coatings are also used in the cloth to give the look of solidity and weight which are not always present. Clay is often applied heavily to loosely woven cotton materials. The dressings or coatings used for cotton yarns are too numerous to mention, and are employed in various combinations.

Counts or Numbering. — In the United States cotton yarn is counted by the number of hanks of 840 yards in the pound. No. 1 yarn (the coarsest, but it is seldom used) would have 840 yards in one hank, which would weigh one pound. Number 20s single would have 20 hanks of 840 yards each, or 16,800 yards in all in one pound. Single 20s yarn would be written $\frac{1}{20}$s or $\frac{20}{1}$; two-ply 20s would be written $\frac{2}{20}$s or $\frac{20}{2}$ and 16,800 yds. would weigh two pounds — or 1 lb. would contain only 8400 yds. of $\frac{20}{2}$ ply.

Sewing cotton is twisted into three cord (three threads twisted together) and also into six cord (three two-ply threads twisted together), but as the latter is smoother, stronger, and better adapted to the sewing machine, it is more in demand as serving both purposes. Three-cord sewing cotton number 60 would be expressed $\frac{3}{60}$s, and six-cord would be $\frac{6}{60}$s. A three-ply No. 8 yarn ($\frac{3}{8}$s) would be a coarser thread than single No. 8 ($\frac{1}{8}$s), for three threads of number 8 would be twisted together. Number 60, six-cord yarn, and number 60, three-cord yarn, are made the same size, but in the former case a finer yarn is used in the combination.

Winding, Spooling, Warping, and Drawing-in. — The preparation of cotton warp yarn for the loom is similar to that of other textile fibers, *i.e.*, winding the yarn into hanks, spooling it, warping it, slashing or sizing, and threading the yarn through the harness. (See Chap. III.)

Weaving (see Chap. IV). — A large number of standard cotton cloths, such as muslins, sheetings, many ginghams, percales, and sheer materials like nainsook, batiste, longcloths, cambrics, and lawns, are woven with the plain or cotton weave, as it is sometimes called. There are very slight differences in the body and feel of these materials until after the finishing. Regular twills and broken twills are found in denims, galateas, and sateens. Elaborate designs made on special looms or on the Jacquard, and double weaves of various kinds are found in expensive and bordered cottons, in fancy ginghams, leno weaves, and embroidered materials, in velveteens, Turkish toweling, and piqués, and in cloths which imitate linen, as in damasks; or silk, as in cotton brocades; and in imitation of wool and worsted materials, such as cotton coverts, chinchillas, beavers, diagonals, and worsted suitings. These materials are very soft and pliable when they come from the loom.

Finishing Cotton Cloth. — Cotton materials depend greatly on finishing for their effect; the only difference between some of the plainly woven materials is in the method of treating the cloth after the weaving, and the resemblance of cotton to other textiles is principally a matter of dressings and machine finishing. So numerous are the dressings used and the processes which follow, that it is possible to indicate only representative methods. By means of these methods feel and appearance are given, such as a soft or supple finish by glycerin, fats, oils, and waxes; or a full finish by starch and pressing; or gloss, as needed in percalines, silesias, and percales, by mucilage, gums, and ammonia water; or high luster by warm dressings and the hot calender and mangle alternately; or stiffness by mucilage and gums as required in linings, swisses, tarletans, and lawns; or weighting with clay that a solid appearance may be gained, as in cretonnes and canvas. To give a dull finish or the appearance of other textiles, special dressings are applied. Waterproofing, preserving, rendering sanitary, and taking away the natural inflammability, are also obtained through dressing. Elastic finishes are dependent to some extent on hand work. The material is starched, dried, beaten, squeezed, and worked by hand in all directions. Finishes are apt to pass off to some extent in the laundry, and the loss of the finish and crisp feeling, as in organdies, makes such materials unattractive, but starching or stiffening in the laundry restores to others much of the original appearance.

Cottons having designs woven in, such as fancy ginghams and madras, have frequently long warp or filling floats on the back. These threads are cut off by a special machine. When the designs are small, as in polka dots and lozenges, there is danger of pulling out the cut threads in home washing unless care is taken. Soft, rather open mesh cotton materials, such as fine muslins and batistes, have to be dried carefully so that the dressing will not settle in the mesh and make the material too stiff.

The calendering is an important part of the finishing of these materials. Some cloths require a soft face and a stiff back and are treated on both sides, as in piqué. Percales and calicoes also depend greatly on the finish. The face is shorn or singed to get rid of the fluff, and after dressing they are treated like sateens and beetled to soften them. Dimities are finished with light farina sizing, the cloth being delivered to the size in large folds, and the rollers with the preparation upon them pass back and forth over the cloth. The material is dried, and as it is apt to shrink it is stretched on tenter frames an inch wider than necessary to allow for further shrinkage in the calendering.

Many of the finishes are expensive, and make the cost to the consumer rather high. This is especially noticeable in the fine cottons which have been carded, double-combed, and finally given the most delicate finish, as in some of the exquisite French cotton dress goods. Enormous cotton finishing machines are used in large mills, and turn out 5000 yards a day, each finisher keeping five hundred looms busy.

Cotton is made to look like wool or worsted in various ways: first, by the preparation of the yarn; second, by weaving the cotton yarn into wool or worsted patterns; third, by chemical treatment or parchmenting to give the look of wool; fourth, by "animalizing" or so treating that cotton will dye in the wool bath; fifth, by dressing and calendering with rollers covered with cloth to give a rough or woolly appearance, or passing the cloth through a napper and shear. Outing flannel, flannelette, pile goods, and blankets are napped by being passed several times over cylinders covered with card clothing. Cotton requires more delicate manipulation in the napping gig than wool, for it is much softer and is less elastic. So-called woolen glove linings are frequently of cotton made to look and feel like wool, or the cotton is combined with a little real mohair or other wool.

To make cotton cloth look like linen requires much dressing, for the fiber of the former is soft, while flax has body. To give the effect of the shiny, long, smooth fibers of flax, which reflect the light, the cotton fabric has to be pressed down after dressing and then beetled, which makes the surface glisten like linen. Cotton toweling looks like linen on account of the yarn being spun with small knots in it at intervals, the design for the weaving being one of the ordinary huck or toweling weaves, and the dressing and finishing completing the resemblance. Linen is absorbent to moisture, and cotton can be made so by treatment, but the water does not evaporate from it the way it does from linen. Unfortunately, after laundering the cotton towel loses the effect of linen. By heavily loading closely woven cotton cloth and pressing it, cotton canvas can be made to look much like linen, and at a very much lower cost.

Silk effects are largely the preparation of the yarn in mercerizing (see Chap. XII), in weaving of a silk pattern, in gassing, dressing, and pressure. Satin finish for cotton sateens is gained by dressing with glycerin, and passing repeatedly through the calender. Glauber's salt gives the luster of silk, and common salt the " scroop " or rustle. Mercerized yarn woven in a silk pattern as in cotton pongee looks and feels like spun silk. Velveteens, corduroys, and cotton velvets (see Pile Fabrics, Chap. IV) require elaborate finishes after weaving, which differ according to the purpose and quality of the material. They may be, as in cheap velvets, lined and stiffened for cutting, after which they are soaked, washed, and hydro-extracted, which removes the stiffening that aided in the cutting. They are then brushed, shorn, brushed again, singed, brushed. The cloth now has a brownish appearance, and is frequently bleached before dyeing or staining. In the cheapest velvets a stain is put on the surface instead of full dyeing. They are finally finished by waxing the pile side, brushing the wax in to give polish, and peg finished by stroking the cloth across the width. A final brushing prepares the cloth for sale. In better classes of materials the pile is sometimes raised by forcing steam through.

Embossing machines make patterns in relief. After the material has a stiff finish, dots, checks, and twills can be placed upon it, but they pass away in the laundry. To represent embroidered cottons, dots of paste are printed on swiss; these will stand a little careful washing, but are darkened by the pressing iron.

Absorbent cotton is made by depriving the fiber of its oil, wax, and mineral salts. It will then take moisture rapidly. For surgical purposes the cotton must be very pure and kept absolutely sterilized. New Orleans, Texas, and Mobile cottons are considered good for this purpose.

Cotton Printing and Printing Machines. — The designs on cotton goods are frequently printed on the cloth instead of being woven in; calicoes or prints, percales, galateas, cretonnes, silkalines, lawns, and figured organdies are printed. There are several methods of printing, — by resist, *i.e.*, printing before dyeing in such a way that the dye bath does not change the color (see Chap. XIII); by discharge, in which the fabric is dyed and so printed afterward that the color of the design is removed (Chap. XIII), or by the direct method. In the past, direct printing was first by stencils and then by blocks on which the designs were cut, a separate block being used for each color which was to appear in the design. The cloth was stretched on a framework or table, the blocks were dipped in the dye and then pressed by hand on the cloth. This method is still in use by hand workers. Hand block printing is considered enduring, but is expensive, and machine methods of several kinds have superseded it. The customary way at present is by cylinders on which the design is cut or stamped. These revolve against flat rollers which are in contact with the color troughs. Any excess of color received by the cylinder is taken off with a knife, that the impression may be clean. There are as many cylinders as there are colors in the design, even twenty being sometimes used. These cylinders impress the pattern on the cloth in such succession as is needed; calicoes are usually stamped in one color only. If the background is to be in color the material is usually dyed first and the figure is stamped on later. Printing machines have usually a large drum over which passes an endless cloth into contact with the engraving cylinders, and the material to be printed is carried along by the cloth. As the drum is warm the color is quickly dried. The cotton material has to be prepared so that it will take the impression readily, and the woven cloth has to be bleached, if a white or light color is wished. Bleaching again takes place after printing when a very clear, white surface is required. The color is fixed by steam. Calendering under heavy pressure is given when gloss or luster is required. A breaking machine, which has blunt, spiral knives which come in contact with the surface of the cloth, softens the gloss. The material is finally pressed between pressboards in the hydraulic press.

Preparing the designs for machine printing is done by two processes; in both copper rollers are used to give the impression. In one method the die is cut of soft steel, which is hardened and pressed against soft steel to make another die with the reverse of the pattern. These dies are pressed against copper cylinders and reproduced regularly along the length. The cylinders are placed as required in the printing machine and carefully adjusted that the pattern may be perfect. When the design has served its purpose and will not again be required it can be scraped from the cylinder, which can thus be used again. Printing establishments often have very large sums of money invested in cylinders, which are kept in a storeroom ready to be used again or to be impressed with new designs.

The second method is by the pantograph. The design is drawn five times the required size, inked, and pressed on metal (zinc). It is then etched in and the design placed in a machine, which reproduces it in one fifth the size along a copper cylinder covered with varnish. This takes the impression which is later engraved upon it.

Manufacturing of Cotton. — The United States consumes more than a third of her own cotton crop in her mills, and the manufacturing interests are increasing. In the production, handling, and manufacturing of cotton nine million people are at work. In the year from 1911 to 1912 the United States exported 10,502,000 bales of 500 pounds each, and also 476,778,499 yards of cotton cloth, at a value of $31,388,998. We send our raw cotton principally to Great Britain and the continent of Europe, and our manufactured cloth to China and the West Indies. The South presents special inducements for cotton manufacture; the fields are near, the atmosphere is humid, labor is cheaper than in the North, and labor laws are less strict. The output from the South is principally print cloth, cotton toweling, sheeting, cottonades, drilling, bags and bagging, mosquito netting, wadding, ticking, muslins, and other lower grades of cotton materials.

The Northern mills make sewing cotton and both high and low grade goods. The output covers yarns, — coarse, fine, and mercerized, — hosiery and knitted goods, carded and combed yarns from Peeler, Egyptian, and Sea Island cottons, sewing threads, blankets, fancy ginghams, materials made of a union of silk and cotton, Jacquard cottons, dimities, chambrays, crêpes, lenos, Persians, sateens, novelties, velvet, corduroys and plushes, duck, upholstered goods, such as tapestries and brocades; lace, chenille curtains, cotton coverts and flannels, ropes, webbing and twine, prints, denims, batistes, nainsook, plaid muslins, gauze, bunting, percales, seersucker, damasks, challies, and absorbent cotton.

In general, the United States does not manufacture the finest classes of cotton goods: France is perhaps preëminent. The principal cotton manufacturing centers of the United States in the North are Massachusetts, Rhode Island, and Pennsylvania, and in the South, South Carolina, North Carolina, and Georgia. Fall River is the largest cotton manufacturing town in the world, having four million spindles at work; the specialty is coarse cottons and prints; New Bedford is the center of fine goods. Birmingham, England, is said to be second to Fall River as a cotton manufacturing town.

The United States imported in the year 1911–1912 49,856,-600 yards of cotton cloth, and 5,742,900 yards of cotton yarn. The bulk of the yarn spun in the United States is seldom finer than 60s. In 1912 there were 29,500,000 spindles in the United States, 56,750,000 in Great Britain, 42,500,000 on the Continent; making a total of 128,750,000. Great Britain is preeminent in cotton manufacture in the world. Realizing that competition is close, she has looked more to details than other countries. She is expert in manipulation of stock, and in general uses the finer raw cottons. Germany is advancing rapidly in cotton manufacture.

COTTON MATERIALS

	Width	Price
Batiste	40–45 in.	$0.25–.75
Birdseye	45 in.	.25 up
Bobinet	18–22 in.	1.00 piece
Brussels net	72 in.	.50–1.50
Buckram — double-faced fabric	36 in.	.12½ up
Bunting	27 in.	.05 up
Burlap	42–57 in.	.35–1.00
Calico	27 in.	.08
Cambric	36 in.	.14–.25
Canton flannel	25–36 in.	.08–.25
Canvas, Java	18–36 in.	.25–.70
Challie	25–32 in.	.06–.25
Chambray	32 in.	.12–.45
Cheesecloth	36 in.	.03–.10
Corduroy	21–27 in.	.50–.85
Cotton batting		.05 roll
Crash	24–36 in.	.05–.15
Crêpe	27–44 in.	.18–1.00
Cretonne	30 in.	.25 up
Crinoline	19–36 in.	.12½ up
Damask	1 yd.–2 yd.	.25 up
Dimity	30–32 in.	.10 up
Drilling	24 in.	.15 up
Duck	27 in.	.12½
Flaxon	32–36 in.	.18–.30
Galatea	27 in.	.15
Gingham	32–36 in.	.12–.50
Grenadine	30 in.	.08–.10
Handkerchief lawn	29 in.	.15–.25
Huckaback	18 in.	.10
Indian Head	36 in.	.16
Jean	28–30 in.	.15
Khaki	36 in.	.18–.50
Lawn	32–40 in.	.08–.25
Linon	30–36 in.	.12½–.40
Longcloth	36–42 in.	1.25–3.00 piece
Madras	32 in.	.25–.50
Marquisette	45 in.	.50–.75
Moreen	18 in.	.50
Mull	30 in.	.18–.20

COTTON MATERIALS — *Continued*

	Width	Price
Muslin, unbleached	36 in.	$.05–.15
Muslin, bleached	36 in.	.08–.15
Nainsook	36–45 in.	1.50–3.00 piece
Nearsilk	36 in.	.18–.26
Organdie	68 in.	.30–.90
Outing flannel	27–36 in.	.08 up
Percale	36 in.	.12½ up
Percaline	36 in.	.20 up
Persian lawn	32 in.	.25–.50
Piqué	27–40 in.	.18–1.25
Poplin	27–36 in.	.18–.25
Ratine	27–54 in.	.18–3.00
Sateen	32–36 in.	.18–.40
Scrim	24 in.	.20 up
Seersucker	27 in.	.12½ up
Silesia	36 in.	.10 up
Silkaline	27 in.	.15
Swiss muslin	27–31 in.	.12½–.25
Tarleton	48 in.	.12½ up
Ticking	36 in.	.12½ up
Velour	36–42 in.	1.50 up
Velveteen	22–27 in.	.50–1.25
Voile	27–40 in.	.12½–1.00

CHAPTER VIII

SILK

THE filament which is obtained from the cocoons of the cultivated silkworm makes the costliest and most beautiful textile fabric. A variety of materials are made from it, ranging from filmy chiffon and lace to the heaviest plushes and grosgrains, and from soft, dull finishes to the most crisp and glossy ones. For those who can really afford it the properties of pure, well manufactured silk justify the expense, for beauty, cleanliness, and endurance are combined. The popularity and demand for the fabric at a low price have caused adulterations of it and substitutions of other fibers for it, whereby the natural qualities are altered and we can no longer rely on it or know, even when paying a good price, whether it will wear well or not. The issue is not against low priced silk which looks like the best, for this has distinct advantages, but in the fact that there is generally little certainty when a high price is paid for a supposedly enduring material that the silk will wear. Honest guarantees exist, but the term " guarantee " has been used so carelessly that it has largely lost its significance. The economical consumer who is a judge of textiles has two needs or desires, one of which is to gain temporary effects at a small expense, which she can have by purchasing silk combined with other fibers. For such purposes as millinery, hair ribbons, sashes, and neckties, for passing fashions to be used for one season only, for light colored garments in which change is better than cleansing and for the outgrowing of clothing the cheaper silks are a boon. The consumer, however, has a second need for which she is perfectly willing to pay if she can be assured that she is obtaining what she wishes, *i.e.*, pure silk materials which will endure for a long time for upholstery, hangings, umbrella covers, underwear, petticoats, and serviceable gowns.

It is distressing to the woman who knows the limitations of the cheaper textiles and desires to buy the best, to have so little assurance that her money is being wisely spent. The most careful experiments in the laboratory are the only satisfactory tests by which even the expert can be sure that a piece of silk having the feel and the look of the best will endure. The manufacturer who made the goods is the only one who can tell the content, and, if adulterants have been used, even he is likely to be much in the dark as to the exact percentage of the weighting. Every woman should know the present ways of treating silk and the prices which should be paid for pure silk, that she may be on her guard. She should ascertain the names of reliable manufacturing companies, and try in her own shopping to distinguish between silks she wishes for temporary use and those she wishes to endure. The manufacturers state that they are only too glad to provide good guaranteed stock, if women honestly wish it and will pay for it. The consumer should make it possible to do this without loss to the manufacturers. Women's lack of knowledge is a large factor in the unreliability of the purchased materials. Fabrics indeed are in the shops which are not enduring, being defective in the weave as well as from treatment, for they are made at a low price for effect alone. There are also light, gossamer-like silks which are very strong, and heavy silks are made for temporary appearance as well as for endurance. Stiff, shiny, luster silks are for sale which are strong, yet many varieties of this class of goods are so unreliable that consumers fear to buy. Some manufacturing firms have tried to provide the market with an honest guaranteed article, but have not had the encouragement they should have had, on account of the ignorance existing and the fact that fashion changes so rapidly that many women no longer wish the old enduring silks. The economical consumer, however, is awakening to her responsibility and is beginning to study the entire subject. She will soon demand a knowledge of conditions and what she can do to be assured that her money is well spent.

Properties. — The properties of cultivated silk give it preeminence among textiles when it is pure and well manufactured, for such silk combines strength, lightness, cleanliness, durability, high luster, and beauty. The characteristics of wild silk differ somewhat from the cultivated.

Softness. — Silk, especially after the gum is removed, has an unusual degree of softness, which is of value in the manufacture of some of the most exquisite materials.

Fineness. — The diameter of the filament ranges from .013 mm. to .026 mm., or .0005 to .0010 inch, while cotton ranges from .0005 to .0009 inch, and linen from .0015 to .006 inch.

Specific Gravity. — The weight of silk is the lowest among textile fibers after the gum is removed, consequently light weight fabrics can be made from it.

Endurance. — Pure silk will last for years, even though given hard wear.

Strength. — It is the strongest of all the fibers in relation to its size when the gum has not been removed. On account of this quality it is used in scientific experiments of a delicate nature. Weighting (Chap. XII) decreases this quality.

Tenacity. — The tensile strength is about one third that of the best iron wire, or about 64,000 lbs. per square inch. It loses some of this quality when the gum is removed.

Elasticity and Ductility. — These qualities are high in silk which has not been boiled off, and a thread may be stretched from one seventh to one fourth of its original length. Weighting decreases elasticity and ductility.

Electricity. — It is a poor conductor of electricity, but a good generator. This quality makes it difficult to manipulate in a hot, dry atmosphere. Humidifiers are used in mills to overcome it, and lessen breakages.

Heat Conductivity. — It is not a good conductor of heat, consequently even when it is wet it feels warm in contact with the body.

Cleanliness. — Silk sheds dust, and experiment has shown that germ life does not increase as rapidly on it as on some of the other textiles.

Transparency. — The transparency of some of the woven material lends attraction.

Luster. — This quality in silk is in excess of other textiles. It can be increased by treatment, and the removal of the gum increases the glossiness. Mordanting and weighting in the dyeing decrease it. The gloss of silk is easily destroyed by careless washing. Hard rubbing breaks the filament, weakens the material, and takes away the luster. Silk is easily scorched.

Scroop. — The crisp, crunching sound associated with silk is a quality natural with some silks; it is lost under some treatments and restored by a bath in dilute acetic acid and drying without washing.

Hygroscopicity. — The power of absorbing water, dye, or other substances in solution is very great. In dry weather the content of moisture is about ten per cent, but three per cent more may be taken in wet weather. The weight may be still further increased through artificial means as much as thirty per cent; therefore, according to expert statement, the amount may become ten plus three plus thirty per cent, or forty-three per cent. The universal standard of eleven per cent is added to the absolute dry weight to represent the usual absorption of moisture from the normal atmosphere.[1] The moisture in thrown silk is about the same. Raw silk contains slightly more moisture than boiled-off silk, as the sericin is more hygroscopic. Because silk has a great absorptive capacity, it takes dyestuffs more readily, perhaps, than any other fiber, but the technical difficulties connected with the process are

[1] *The Value of Conditioning*, 1908. Issued by the United States Silk Conditioning Co.

greater than with wool. Its avidity for moisture and its quick absorption of metallic salts have caused the practice of restoring the weight lost in boiling off by adding more or less foreign substance.

Life History. — The silkworm has been cultivated for many centuries on account of the filament which it spins. Roughly speaking, there are two general varieties of silk, the cultivated, produced by the *Bombyx mori*, and wild silk from uncultivated moths such as the Tussah. The name *Bombyx mori* comes from the family to which the silkworm belongs, the *Bombycidæ* (spinners), and *mori*, from the *Morus multicaulis* or mulberry tree, on the leaves of which it feeds. The species *Sericaria mori*, or silkworms of the mulberry, belongs to the class *Lepidoptera* or scaly-winged insects. The *Bombyx mori* is divided into other groups according to the method of reproduction. The annuals reproduce once a year, and sixty per cent of the silkworms belong to this class. The bivoltines reproduce twice a year, and the polyvoltines several times during the year, the first crop after cold weather being the best. Silkworms are cultivated by large breeders, or by small farmers, who with all of their families work together in the silkworm nurseries. The eggs are bought from growers who devote their time especially to reproduction, the best cocoons being kept for this purpose. In some countries there is strict government inspection to prevent the spread of disease. The manner of cultivation and the fertilization and growth of the mulberry are important factors in successful rearing. In 1908 Japan had one half a million families who were giving their entire time to silk culture. The yield that year was 300,000,000 pounds of undried cocoons. In temperate climates the silk is apt to be strong and even. In the tropics it is soft and bright. Bengal silk is excellent, but some of the tropical silk is lacking in strength. The silkworm which breeds once a year in temperate climates is considered the best.

The cultivated silkworm passes through four changes in its life of a couple of months, *i.e.*, egg, larva, chrysalis or pupa, and adult, — a cream-white moth which is about one inch in length (Fig. 105). Mating follows; the female lays several hundred eggs. She scarcely moves three inches during the three days of life, the entire life of male and female being devoted to producing

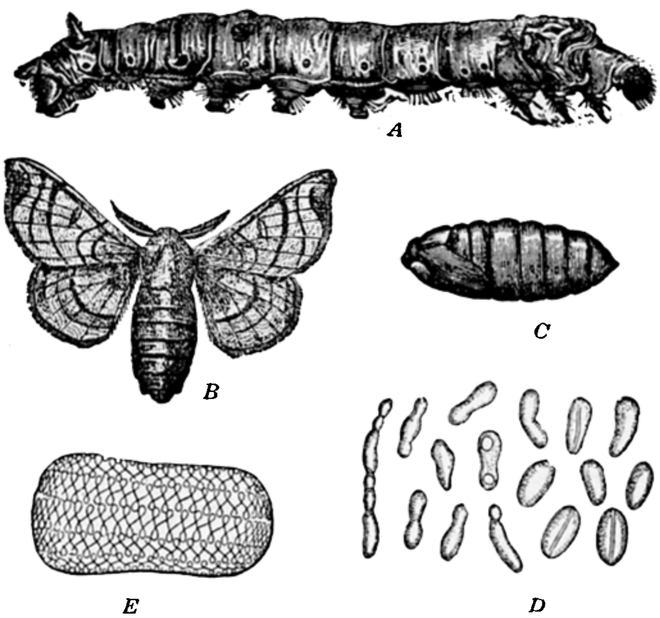

FIG. 105. — DIFFERENT STAGES IN THE GROWTH OF THE SILKWORM.
A, Full Size. *B*, Moth. *C*, Chrysalis or pupa. *D*, Eggs. *E*, Diagram showing cocoon and method of spinning.

From Matthews' *Textile Fibres*, by courtesy of John Wiley & Sons.

eggs. The eggs are laid on sheets of paper or pieces of muslin provided for that purpose. A slightly gummy liquid comes from the moth and holds the eggs fast. The sheets are gathered, hung for a few days in a damp atmosphere, and then placed in cold storage for about six months, the period of cold being advantageous for later hatching, which is done by heat. The worm sheds its skin four times; the times between the molts, or ages, as they are called, are as follows: (1) birth to first molt five or six days; (2) first to second molt four days; (3) second to third molt four to five days; (4) third to fourth molt five to seven days; (5) fourth molt to maturity seven to twelve days. The time between ages varies with different silkworms. Trays are provided to hold the different ages of worms and there are open shelves on which the trays can be placed that the worm can be watched. The cocooneries where the silkworm is best cultivated are quiet, spacious, well-ventilated rooms or buildings where an even temperature is maintained. Each worm is kept absolutely clean and has plenty of room, as overcrowding brings disease. Mild fumigation is resorted to at intervals. Heavy odors such as garlic or tobacco smoke are not allowed, being disturbing to the worms. The best food for the *Bombyx mori* is the perfect leaves of the white mulberry, which must be young, fresh, and dry, but never withered. They are chopped fine during the early ages of the worm. The tree is cultivated especially to provide food for the silkworm. Three varieties are found, the early, medium, and late-budding mulberry. The leaves, therefore, can be found in condition for the various stages of growth of the worm. The late-budding tree is cultivated in greater numbers, as the worms are larger and consume more leaves. The soil is important, and one which is rich in certain minerals has been found to provide leaves which keep the worm in better physical condition. A cold winter followed by a warm spring develops the leaf well. Two prime requisites for good silk are the state of the leaves and the choice of the eggs. When the leaves of the early mulberry are almost ready, the eggs are brought out from cold storage and subjected to heat for a month or less before they hatch out. The eggs are small, dark, flat, and round. The worm, when hatched, is about the diameter of a hair and less than three fourths of an inch long. It gnaws a hole in the end of the egg from which it issues. Showing under the magnifying glass are long hairs, many legs, and a shiny nose.

At first they merely suck the sap of the leaves provided for them, but later they gnaw the edges with their semi-circular jaws which move sideways. The noise of many full-grown worms eating is like the sound of rain. About thirty meals a day are eaten in the first age, for the worms are gluttons and eat their own weight daily. The development is very rapid, and during the next few weeks, as has been stated, the skin has to be changed four times. After the first molt the worm is lighter in color and requires more room; after the second, the spinning organs are more marked; after the third, the leaves do not need to be chopped. After the fourth molt the worm is full sized, about three inches long, white and velvety, and the spinning glands are full of transparent liquid. Hunger lessens, restlessness grows, and the lifting of the fore part of the body indicates the desire to climb and to spin. Brush or twigs are provided and the worm climbs into them and begins to inclose itself in its silken shell by expelling, from two openings underneath the mouth, two delicate threads which form a single one on issuing. They come from the internal glands, and the liquid hardens as it comes to the air. At first the silk is rough and is thrown out like guy lines on the twigs by the motion of the body. Gradually the worm incloses itself in the interior as it forms the cocoon. The method of spinning is by a movement of the head as if making a figure 8, weaving back and forth. (See Fig. 105.) The silk is a continuous double thread fastened together by the gum, the length varying from three hundred to fourteen hundred yards. The worm can be seen for a day, but gradually disappears, though it can be heard working within. It takes three days to complete the cocoon. The silkworm wastes away as the silk is exhausted, and gradually changes into a chrysalis. From fifteen to twenty days are spent in this state, and then the chrysalis changes into a moth which moistens the end of the cocoon and breaks its way out. The female cocoon is oval and the male cocoon is peanut shaped. The silk consists of two parts: fibroin (the silk fiber), and sericin (the gum). On the outside of each cocoon is coarse,